FLORISTIC COMPOSITION AND PATTERNS OF REGENERATION OF RAINFOREST TREES IN THE FRAGMENTED FORESTS OF THE ANAMALAI HILLS, SOUTHERN WESTERN GHATS

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By

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CERTIFICATE

This is to certify that Ms. Priya Balasubramaniam of the Wildlife Institute of India has carried out original research titled **"Floristic Composition and Patterns of Regeneration of Rainforest Trees in the Fragmented Forests of the Anamalai Hills, Southern Western Ghats"** towards the partial fulfillment of the Master of Science (Wildlife Science) degree from Saurashtra University, Rajkot, India. These investigations were carried out under our supervision from November 2002 to June 2003. We also certify that this research has not been submitted for any other degree to any university.

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SUMMARY

The word diverse is almost a synonym for tropical rainforests. In no other habitat are found such an enormous number of life forms. These highly diverse systems are now facing severe threats as a result of habitat fragmentation. The aim of this study was to study the floristic composition and patterns of regeneration in the fragmented forests of the Anamalai hills, southern Western Ghats.

Six fragments were chosen which varied in size and disturbance levels. They were- Iyerpadi (>2600ha), Andiparai (>185ha), Puduthotam (92ha), Pannimedu (66ha), Varattuparai 1c (11ha) and Varattuparai 4 (4ha).

Quadrats of 3 sizes were used to sample for different variables. 20 x 20m quadrats were used to enumerate tree sp, 5 x 5m quadrats were used to enumerate sapling sp and 1 x 1m quadrats were used to count the numbers of seedlings. Height (m), GBH (cm), lopping / cutting signs, altitude, canopy cover, presence of weedy shrubs and ground cover of weedy herbs were the other variables measured. A total of 112 quadrats were laid, 25 in the first 4 fragments, 9 and 3 in the last two respectively.

The findings revealed that tree and sapling generic richness showed a negative relationship with disturbance and time since isolation. Their correlations with area though positive were weak. Fragments were subjected to varied nature and

levels of disturbance. Fragment characteristics such as area, time since isolation did influence the patterns of tree and sapling composition though weakly. There is an extremely weak correspondence between the tree and sapling composition of each fragment. There was a high number of non rainforest species in fragments which were relatively more disturbed. Relatively undisturbed fragments were more rich in rainforest trees and saplings. Fragments showing higher levels of canopy openness were relatively more disturbed than others. Disturbed fragments also showed higher levels of weed invasion. Iyerpadi showed the highest generic richness in trees and saplings. Varattuparai 4 showed the least richness in both trees and sapling. Human disturbance due to its chronic nature was the principal predictor of both tree and sapling composition.

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1. INTRODUCTION

Tropical rainforests are one of the most diverse and species rich habitats with respect to both flora and fauna (Richards, 1981). One of the features of the tropical rainforest is high species richness and low abundances of individual species. This is largely due to the differences in habitat and regeneration niche specialisation (Hubbell and Foster, 1986). The richness of the tree flora is indeed one of the most important characteristics of the tropical rainforest and on this many of its other features are directly dependent (Richards, 1996).

The tropical rainforests have received much attention as they act as reservoirs for much of the biological diversity in the world. Unfortunately, they have been extensively exploited with large tracts of virgin forests being cleared at alarming rates for pastures, tea, coffee, teak plantations, construction of dams and other commercial ventures (Saunders *et al.* 1991).

To add to the problem, the remaining forests exist as isolated fragments in a structurally and functionally different habitat mosaic and are subjected to continuous anthropogenic pressures. Such isolation coupled with reduction in size of the remaining fragments can result in degradation of the habitat quality of the existing fragments (Saunders *et al.* 1991).

Research on the forest dynamics of rainforests have explored a wide variety of patterns and relationships such as effect of light on woody seedling regeneration (Nicotra *et al.*1999), patterns of seedling survival of particular tree species (Nichols, 1999), advantages of directed seed dispersal (Wenny, 2001), gap-phase regeneration of pioneer and primary forest species (Brokaw, 1985, 1987) and specific studies, which monitor the growth and mortality of seedlings of a particular tree species (Puig and Fabre, 1997).

With the increase in awareness on the effects of habitat fragmentation, a whole range of studies on the effects of habitat fragmentation were undertaken. A wide range of issues, starting from patterns of species loss (Andersen *et al.* 1997), dispersal and dynamics of genetic structure in fragmented tree populations (Nason *et al.* 1997) to specfic issues such as regeneration of large seeded trees (Harrington *et al.* 1997) was undertaken principally in the neotropics.

In the Indian scenario, rainforest fragmentation has been most extensive in the Western Ghats, with extensive areas of forest cleared for the plantations of tea, coffee and other cash crops . 60%of the forest area occur as fragments less than 20 sq km in area (Kumar *et al.*1998).

Studies on the effects of rainforest fragmentation in the Western Ghats has been few (Kumar *et al.* 2001) and fewer with respect to the changes in floristic composition and regeneration (Lall, 1990).

The tropical rainforests of the Anamalai Hills in southern Western Ghats, have experienced severe habitat fragmentation due to the conversion of the once continuous tropical rainforests to cash crop plantations of tea and coffee, eucalyptus and teak since the 1880's till the 1970's. More than 60% of the remaining rain forests occur as patches of a few hectares to 20 km^2 (Kumar, 1998). It has been documented that in a 1920-1970 period there has been a four fold increase in the number of fragments found today (Ramesh *et al.* 1997). The remaining isolated forest fragments range in sizes of <1 ha to >200 ha and have been subjected to continued human disturbance (Kumar *et al.* 1998). Thus, this forms an ideal study site for the study.

1.1 OBJECTIVES OF THE STUDY

The following were the objectives of the study

- What are the trends in fragment characteristics across fragments?
- What are the trends in tree composition across fragments?
- What are the trends in sapling composition across fragments?

How are the trends in tree and sapling composition influenced by human disturbance, area, altitude and time since isolation?

2. STUDY AREA

2.1 THE WESTERN GHATS

The Western Ghats are a 1400km long chain of mountains that run almost parallel to the west coast, mainly30-40km inland (Nair, 1991). These hills traverse through the states of Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra and Gujarat covering an area of about 160,000 km^2.

The Western Ghats are geologically complex, not conforming to any particular geological formation. In the extreme south (south of Shencottah Pass at 9°N), is Khondolites, consisting of gneiss and schists with silimanite and garnet. Between 9° and 13°N (Kodagu), Charnokites dominate, consisting of granitoid gneiss with pyroxene and hypersthene, which are ferro-magnesian minerals (Pascal, 1988).

Altitude governs the temperature in these areas, with the mean annual temperature varying from 28°C at sea level to about 15°C degree at 2,000 m, with the mean minimum temperature being ca. 5°C at 2000 m (Pascal, 1988). The wide variation in rainfall, temperature and altitude is reflected in the variety of vegetation types in the area, consisting of evergreen, semi-evergreen, moist-deciduous, dry-deciduous, montane, sub-tropical and temperate forest (Pascal, 1988). The forests of Western Ghats sustain 5.2% of known plant species and 4.3% of known animal species of the world (Nair, 1991). Of the 15,000 sp of angiosperms in India, 5000 are from the Western

Ghats (Nair and Daniel, 1986). There are about 58 endemic genera mostly confined to the Western Ghats, of which 47 are monotypic (Nair, 1991).

2.2 THE ANAMALAIS

The area chosen to conduct the proposed study were the forest fragments found in the Anamalai Hills and within the Indira Gandhi Wildlife Sanctuary(10 ^{0} 12'and 10 ^{0} 54'N and 76 ^{0} 44' and 77 ^{0} 48'E) located in Tamil Nadu (Plate 1)The Sanctuary was created in 1976 and covers an area of 987 km^2. It is located mainly in the Valparai taluk but extends to the Pollachi and Udumalpet taluks as well. It extends 45 km north-south and 25 km east-west. Three major public roads pass through the Sanctuary- the Pollachi-Chalakudi road through Valparai, the Pollachi-Parambikulam road through Topslip and the Pollachi-Munnar road through Udumalpet range.

Almost in the centre of the Sanctuary is nearly 180 km2 of privately owned tea and coffee estates. In its centre is the Valparai town which served as the field base for the present study. The Sanctuary is bordered by Parambikulam Wildlife Sanctuary in the south–west, the Reserve Forest of Chalakudi Forest Division and Eravikulam National Park in the south, Chinnar Wildlife Sanctuary in the south–east and by cultivated plains in the east.

ALTITUDE

The altitude of the Sanctuary ranges from 220m in the plains in the east to 2,513 near Grass Hills. Hilly tracts form over 90% of the total area, extending north-west to south-east. The central portion around Valparai town is at an elevation of 900-1500m and has extensive tracts of tea and coffee plantations (Kumar *et al.*1998).

SOIL

The soil found in the Anamalai Hills has been classified as lateritic soil (Krishnan, 1982). It is a porous, pitted, clay-like rock with red, brown, grey and mottled colours depending on the composition. The rocks found here are classified as metamorphic and igneous and their origins have been estimated to have been from the Pre-Cambrian period.

RAINFALL

Rainfall varies considerably, ranging from 500 mm in the eastern slopes to 5,000 mm in the western slopes. The Sanctuary receives both the south-west and the north-east monsoon, with most precipitation received from the former. According to rainfall and mean temperature for each month, 3 distinct seasons have been identified (Kumar *et al.* 1998).

1. Dry: characterized by low temperature and no or less rainfall (January to April)

2. First wet (south-west monsoon): characterized by moderate temperature and high rainfall (May to August)

3. Second wet: characterized by moderate temperature and rainfall (September to December)

VEGETATION

Champion and Seth (1968) have classified the wet evergreen forests of the Anamalai hills under Type 1A, C4. West coast tropical evergreen forest. In the Anamalai hills, Tropical wet evergreen forests occur between 600-1600 m. The principal forest type is the *Cullenia-Mesua-Palaquium* series which characterizes the mid elevation vegetation type. The lower limit of this type is 600-700 m and is determined by latitude and exposure while the upper limit is 1400 m (variable). This association may locally constitute 80% of the large trees (Pascal, 1988). The forest department estimates of 1980s show that wet evergreen forests cover about 80km^2 (Kumar *et al.*1998). In the higher elevations (>1700m) tropical montane forest occur with the following dominant tree species- *Gordonia obtusa*, *Michelia nilagirica*, *Temstroemia japonica* and *Eugenia* spp (Pascal, 1988). These forests along with the montane grassland form the shola-grassland complex. An extensive area has been planted with teak between 600-1,000 m (Kumar *et al.* 1998).

PEOPLE

About 200,000 people live in Valparai town and in the 54 estates within a radius of 30km from it. Sizable parts of the population are labourers in the estates .There are about 4,000 tribals in 38 settlements distributed throughout the Sanctuary. Six major tribal communities have been identified namely- Kadars, Malasars, Malamalasars, Eravalars, Pulaiyars and Muduvars (Sundarraju, 1987).

2.3 FOREST FRAGMENTS

The extensive tracts of wet evergreen forests that dominated the landscape have now been reduced to fragments of varying sizes due to the conversion of these forests into tea and coffee plantations, which now cover more than 187km^2 in the centre of the sanctuary (Sundarraju, 1987).Six fragments varying in size, and disturbance levels were chosen for the study. The characteristic features of these fragments are given in Table 1.

Table 1 Some characteristics of the rainforest fragments chosen for the study.

S.No	Fragment	Size (Ha)	Elevation range sampled (m)	Ownership	Surrounding Vegetation	Time since isolation (years)
1	Andiparai	>185	1225-1500	SA	T,S	70
2	Iyerpadi	>2600	1250-1450	SA	T	40
3	Pannimedu	66	1000-1100	P	T,C,R,E	35
4	Puduthotam	92	1080-1175	P	T,C,E	91
5	Varattuparai 1c	11	925-1025	P	T,C	100
6	Varattuparai 4	4	1025-1050	P	T,C,R	100

C-coffee, E-eucalyptus, P-private, R-reservoir, S-secondary forest, SA-sanctuary, T-tea

ANDIPARAI

This large made fragment is located on the Valparai-Pollachi highway and is owned by the forest department. The fragment is characterised by extremely steep and rocky terrain. It extends across the highway to a very limited extent wherin it is bordered by tea which is the only side in which it has been anthropogenically fragmented. The canopy is not very open and the entire fragment has 3 structural layers- the canopy, the ground layer and the understorey. Towards the top of the fragment there is lots of grass, bamboo and shrubs. The tree abundance declines a little as one goes to the top. The fragment is located in a zone where mists are very frequent and hence the inside is always a little cooler. There are also a number of streams that pass through the fragment.

IYERPADI

Iyerpadi , colloquially known as 36th hair pin bend is a very large made fragment. It is also located on the Valparai-Pollachi highway and is fragmented by the road and tea on one side. This large fragment continues as the Akkamalai shola and into Grass hills. The fragment also has steep and rocky terrain and numerous streams course through it. It has lush, rich vegetation. In the past, some parts of the fragment had been under Cardamom cultivation but it has been abandoned for long. The fragment is abundant in the members of family Lauraceae and has quite diverse in trees.

PANNIMEDU

This medium sized privately owned fragment located at 17km from Valparai is surrounded on 3 sides by a man made reservoir called the Sholayar reservoir. The fragment is characterised by slightly steep slopes. The vegetation is not very dense and there is easy mobility through the fragment. The dreaded elephant nettle *Dendrocnide sinuata* is also quite abundant in this fragment. Elephants frequent this fragment due to easy access to a water source nearby.

PUDUTHOTAM

This medium sized privately owned fragment is situated on the Valparai-Pollachi highway right in the heart of Valparai town. The fragment is highly disturbed due to very high fuelwood collection, which has caused considerable damage to the vegetation. This fragment is also subjected to a unique form of disturbance in which the trees are girdled, whereby the bark of the trees are chipped to leave the inner live tissue exposed. Subjected to strong dessication , the tree slowly dies after which it is easy to chop it down and collect the timber. Quite a high proportion of the standing trees and saplings are non rainforest species such as *Maesopsos emenii* and *Coffee* respectively dispersed inside the fragment from the surrounding matrix as well as planted to a certain extent.

VARATTUPARAI 1C

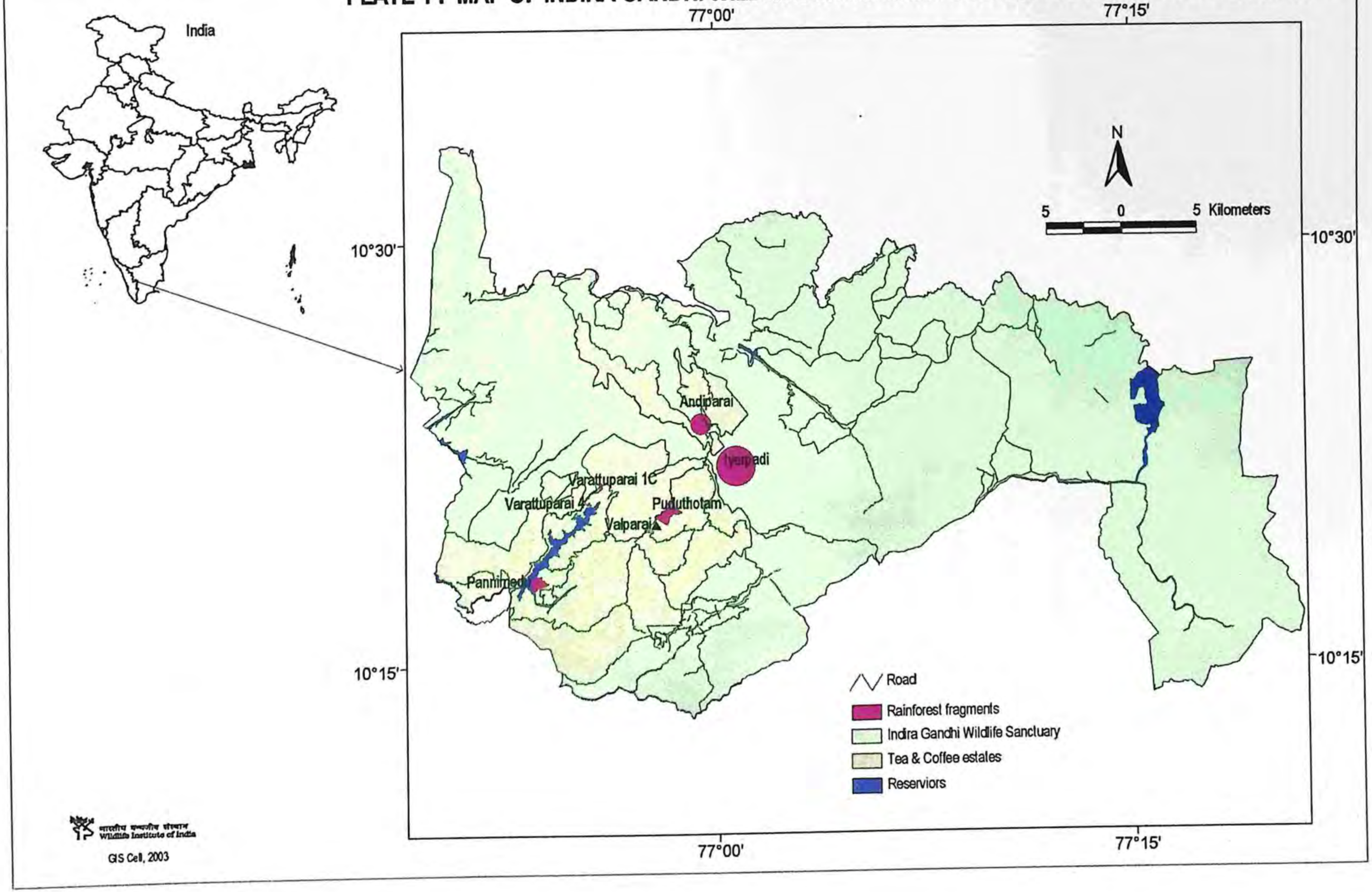
This includes 3 fragments identified by prior researchers as Varattuparai 1, 2 and 3 respectively. The fragment is linear and is bisected by a road. It is quite disturbed and faces pressures such as high fuelwood collection, invasion by weeds such as *Lantana camara* and non rainforest species such as *Maesopsos emenii.* This fragment also has a few settlements colloquially called as labour lines present near it.

VARATTUPARAI 4

This is a very small fragment and extremely linear in shape. The maximum width of the fragment would not exceed 70m. It is a highly disturbed fragment with considerable open canopy and an abundance of weeds such as *Lantana camara*. There are very few trees present in this fragment. This fragment also has a few settlements near it.

Arc View 3.1 and Arc Info 8.1 (ESRI) Redlands, CA was used to develop the maps of the study area.

PLATE 1 : MAP OF INDIRA GANDHI WILDLIFE SANCTUARY SHOWING RAINFOREST FRAGMENTS



3. METHODS

3.1 FIELD METHODS

3.1.1 Selection of fragments

The study was carried out within a five month period commencing from November 2002 to April 2003. A total of six fragments varying in size and disturbance levels were sampled. Two of the fragments were part of the Indira Gandhi Wildlife Sanctuary while the remaining four were under private ownership within the Indira Gandhi Wildlife Sanctuary (see Table 1).

3.1.2 Placement of quadrats

Exisiting forest trails were used to lay quadrats but in places where they were not available the fragment was cut across to lay the quadrats. Quadrats were laid alternatingly at ≥30m from trails (Fig. 1). In the largest fragment, quadrats were usually laid at 100m (minimum 50m) in an attempt to sample relatively undisturbed areas. A 100m interval between successive quadrats was followed wherever possible (Fig. 1). However, in smaller fragments, lower sampling intervals (60m) were used in order to sample the fragment adequately. The distance from any edge to a plot was usually maintained at ≥ 30m. An edge for purposes of this study, is considered as the geographical limits of a fragment. In smaller fragments, area and constraints of shape reduced this distance to a minimum of 11m. Terrains atypical to the fragment, such as bare rocky areas were avoided for sampling. This was usually done in the largest fragment in an attempt to sample typical and relatively undisturbed forest patches.

3.1.3 Vegetation sampling

Quadrats of 20 X 20 m were used for sampling. Within that were laid two 5 X 5 m and five 1 X 1 m quadrats. These 3 quadrat sizes were used to measure different habitat and vegetation parameters. The five 1 X 1 m quadrats were placed one at the centre of the quadrat and the remaining four at 5m from the centre in 4 directions. The two 5 X 5 m plots were placed 5m from the centre (Fig. 1).

3.1.4 Sample size

25 quadrats were laid in each fragment as it enabled the total sampling area to be 1 hectare for trees, 0.125 ha for saplings and 0.0125 ha for seedlings. However, a total of nine and three quadrats were laid in Varattuparai 1c and Varattuparai 4 respectively owing to constraints of size and shape of the fragments. A total of 112 quadrats across six fragments were sampled.

3.1.5 Parameters measured in the 20 x 20 m quadrat

3.1.5.1 Habitat parameters

- Altitude: Altimeter was used to measure altitude at the centre of each quadrat

- GPS: Garmin GPSII was used to take GPS readings of quadrats wherever possible.
- Canopy cover: percentage canopy cover was estimated using a densiometer.

3.1.5.2 Vegetation parameters

All species other than shrubs and weeds which were ≥ 20 cm GBH were considered as trees and the following parameters measured about them.

- Height of trees was visually estimated.
- GBH of trees was measured using a 5m tape. In the case of buttressed trees, two measurements were taken, one along the buttress and a visual estimation of the girth above the buttress. In case of coppiced stems, the girths of the coppiced stems were taken provided at least one of them was ≥ 20 cm. In case of branchings, the girth of the trunk just below the branching was measured.
- Lopping /cutting: lopping / cutting signs on the trees was noted as a measure of disturbance.

3.1.6 Parameters measured in the 5 x 5 m quadrats

3.1.6.1 Vegetation parameters:

- Saplings: all individuals of tree species ≥ 1m height and < 20 cm GBH were considered as saplings and their height and GBH was measured. In case of coppiced stems, the GBH of all the coppiced stems were taken. In case of branchings, the girth of the trunk just below the branching was taken.

- Lopping / cutting signs on the saplings were also noted as a measure of disturbance.
- The presence / absence of weedy shrubs namely *Lantana camara* and *Eupatorium adenophorum* was also noted as a measure of disturbance.

3.1.7 Parameters measured in the 1 x 1m quadrats

3.1.7.1 Vegetation parameters

- Percentage ground cover of weedy herbs namely, *Ageratum conyzoides* was visually estimated as a measure of disturbance.
- Number of seedlings of rainforest and non rainforest tree species was also noted.

A general description of the quadrat was made including notes on presence of dung, disturbance signs such as presence of lopping/cutting, weeds and presence of canopy gaps.

3.2 IDENTIFICATION OF SPECIES

The principal taxonomic key used to identify the tree species occurring in the study area was Pascal and Ramesh, 1987. Other standard floras were also used to identify specimens (Gamble, 1984, Hooker, 1986, Manilal, 1988, Matthew, 1983, Nair and Nayar, 1986). Professors and technicians at the Wildlife Institute of India and Salim School of Ecology, Pondicherry were also consulted during identification. Wherever possible, plants were identified till the species level. In certain families such as Lauraceae, Ebenaceae and Myrtaceae, due to a high level of uncertainty regarding species characteristics, genus or family level identification was attempted. The problem was especially obvious in the identification of saplings and hence, species level identifications were kept to the minimum for saplings of such families.The number of individuals identified till genus was much higher than those that were identified till species hence, analysis was attempted only at the generic level keeping species level inferences to a few specific issues. Species and genus of family Lauraceae that are confusable with each other is given in Table 2.

Table 2 - Species of Family Lauraceae that are confusable with each other.

Species	*L.bourdilloni*	*L.coriacea*	*L.floribunda*	*L.glabrata*	*L.insignis*	*L.laevigata*	*L.mysorensis*	*L.oleoides*	*P.macrantha*	*P.lanceolata*	*A.arnottii*	*C.bourdilloni*	*C.anamalayana*	*Litsea sp*	*Cryptocarya sp*
L.bourdilloni												1		1	1
L.coriacea				1		1		1						1	1
L.floribunda					1									1	
L.glabrata		1				1		1						1	
L.insignis	1		1											1	1
L.laevigata		1		1				1						1	
L.mysorensis										1				1	
L.oleoides		1		1		1								1	
P.macrantha				1						1				1	
P.lanceolata									1		1				
A.arnottii										1					
Litsea sp	1	1	1	1	1	1	1	1	1	1					1
Cryptocarya sp	1	1			1							1	1	1	

3.3 ANALYTICAL METHODS

3.3.1 Fragment characteristics

Hierarchial cluster analysis was used to represent the relationships between fragments in terms of area, time since isolation and range of altitude. The algorithms were chosen depending on which best fit the data. The dissimilarity matrices resulting from the cluster analyses were used in subsequent analysis of fragment characterstics with floristic composition.

3.3.2 Disturbance

- Kruskal-Wallis test was done to test for differences in average percentage of canopy openness across fragments.
- Principal component analysis was used to identify composite factors of disturbance after Z transformation of variables densities/ha of non rainforest saplings, densities/ha of non rainforest trees, densities/ha of non rainforest seedlings, abundances of lopped trees, lopped saplings, cut trees, average percentage ground cover of weedy herbs, percentage frequency of presence of weedy shrubs and average percentage of canopy openness.
- Hierarchial cluster analysis was used to represent the relationships amongst fragments with respect to the above mentioned variables. The dissimilarity matrices resulting from the cluster anlaysis were used in subsequent analysis with floristic composition .

3.3.3 Vegetation structure

- The densities/ha of rainforest and non rainforest trees and saplings was calculated for each fragment.
- Kruskal-Wallis test was done to test for differences in abundances of rainforest trees and saplings across fragments.
- Densities/ha of each girth class, pooled across all fragments were plotted for the ten most dominant species (which contribute >50% of the total abundance.) along with some other species of ecological interest, such as *Palaquium ellipticum.*
- In order to determine whether the proportional abundances of trees was maintained in the sapling class, a Spearman's rank correlation was done on the proportional abundances of genera in the tree and sapling class of each fragment.

3.3.4 Vegetation composition

- Generic richness of trees and saplings was calculated as the sum total of all genera sampled in that fragment. This was then expressed as the generic richness of rainforest and non rainforest trees and saplings.
- Richness of Endemic species for each fragment was also calculated (Ramesh and Pascal, 1997). Kruskal-Wallis test was done to test for differences in generic richness of rainforest trees and saplings.
- Rank abundance plots of trees and saplings were made to see the nature of abundance patterns in each fragment.
- Rarefaction curves for rainforest trees and saplings for 5 fragments (excluding Varattuparai 4, as it had very few trees) were estimated.

- Hierarchial cluster analysis was done to see the dissimilarities between fragments in terms of vegetation composition (densities/ha of genera of rainforest trees and saplings). The dissimilarity matrices resulting from the clusters were used in subsequent analysis with fragment characteristics and disturbance.

3.3.5 Relationships between fragment characteristics, disturbance and vegetation composition

- Spearman's rank correlation was done to understand the relationships between fragment characteristics (area, altitude range, median altitude and time since isolation).
- Spearman's rank correlation was also used to understand the realtionship between the above mentioned fragment characteristics and the factors of disturbance (identified from the factor analysis of disturbance parameters).
- To understand the relationships of fragment characteristics, disturbance and vegetation composition, Spearman's rank correlation was done between generic richness of rainforest trees and saplings with area, altitude range, median altitude, time since isolation and the factors of disturbance.
- Based on the trends obtained from the correlations, variables area, altitude range, time since isolation and the factors of disturbance were regressed against generic richness of rainforest trees and saplings using linear multiple regression with backward selection .

- In order to find out the determinants of floristic composition of rainforest trees and saplings, dissimilarity matrices of rainforest trees and saplings were regressed against dissimilarity matrices of area, time since isolation, median altitude, altitude range and disturbance using RT Version 2.1 (Manly, 1997).

The following software were used for data entry and analysis; Excel, SPSS 8.0 for windows (SPSS Inc, Chicago) and BioDiversity Professional Version 2.

4. RESULTS

4.1 FRAGMENT CHARACTERISTICS

4.1.1 Area

The average percentage of dissimilarity between fragments was 35.76%. Varattuparai 1c and Varattuparai 4 were most similar whereas Iyerpadi and Varattuparai 4 were most dissimilar with areas of 4 and 2600 ha. respectively (Fig. 2).

4.1.2 Time since isolation

The average dissimilarity between fragments was 53.9%. Iyerpadi, with an isolation age of 35 years was completely dissimilar with Varattuparai 1c and Varattuparai 4 which were isolated 100 years back. On the other hand, Varattuparai 1c and varattuparai 4 were completely similar (Fig. 3).

4.1.3 Altitude range

The average dissimilarity between fragments was 25.56%. Andiparai which has the highest altitude range was completely disimilar with Varattuparai 4 whereas Pannimedu and Varattuparai 1c were most similar.

4.2 DISTURBANCE

4.2.1 Varattuparai 4 due to its very open canopy showed the highest average percentage of canopy openness (Mean=5.186%, SE= ± 2.77%) while Iyerpadi with highly closed canopy showed the least (Mean=0.326%, SE= ± 0.06%, Fig 4). The differences in the average percentage of canopy openness between fragments was significant ($KW\chi^2$ =36.257, df =5, $p < 0.01$). The contribution of the understorey either partially or in full to canopy closure was 74.32%. This explains why the absolute value of canopy openess is low, even in highly open places such as Varrattuparai 4.

4.2.2 PCA identified 2 composite factors of disturbance which explained 90% of the variation (PC 1=50.84%, PC2=39.45%). Factor 1 was associated with disturbance in the form of high percentage frequency of presence of weedy shrubs, average percentage of open canopy, abundance of lopped saplings and non rainforest saplings. Factor 2 was associated with abundance of non rainforest seedlings, high average percentage ground cover of weedy herbs, abundance of cut trees and non rainforest trees (Table 3). The fragments that scored highly positive on factor 1 were Varattuparai 4 and Varattuparai 1c whereas the only fragment to score highly on factor 2 was Puduthotam. Andiparai, Pannimedu and Iyerpadi had negative scores on both factors (Fig. 5).

4.3 VEGETATION STRUCTURE

4.3.1 Andiparai had the highest density of rainforest trees (699 trees/ha) while the lowest was recorded in Puduthotam (178 trees/ha, Table 4). However, densities of non rainforest trees was highest in Puduthotam (179 trees/ha). Iyerpadi and Pannimedu are noteworthy in not having any non rainforest tree (Table 4). Iyerpadi had the highest densities of rainforest saplings (10872 saplings/ha) while Varattuparai 4 had the least (2266.66 saplings/ha). While Iyerpadi did not have any non rainforest sapling, Varattuparai 1c with 1644.44 saplings/ha had the highest (Table 4).

4.3.2 The mean abundances of rainforest trees was highest in Andiparai (Mean=27.96, SE ± 1.94) and lowest in Varattuparai 4 (Mean= 8.00, SE ± 2.6, Table 4). The mean abundances of rainforest saplings was highest in Iyerpadi (Mean=54.00, SE± 3.37) and lowest in Varattuparai 4 (Mean=11.33, SE ± 4.17, Table 4).

4.3.3 Rainforest trees differed significantly in their abundances across fragments (KWχ^2 =34.801, df=5, p<0.01) as also did rainforest saplings (KWχ^2 =59.198, df=5, p<0.01).

4.3.4 The dominant species for which girth class distributions were plotted were *Dimocarpus longan, Maesa indica, Litsea sp, Villebrunea integrifolia* , *Maesopsos emenii,, Mesua ferrea, Ardisia rhomboidea Cullenia exarillata* , *Aglaia simplicifolia and Palquium ellipticum* The distributions for the first three species along with *Aglaia simplicifolia, and Ardisia rhomboidea* are similar in being abundant in the first 2 girth classes spanning 1-10cm. *Mesua ferrea* and *Cullenia exarillata* are similar in having higher representation in the highest and lowest girth classes with very low abundance in the intermediate girth classes. *Palaquium ellipticum* showed low densities both in the adult and sapling class with relatively higher densities in the larger girth classes. *Maesopsos emenii* was a relatively evenly distributed species in relation to the other distributions with representations in almost all of the girth classes. *Villebrunea integrifolia* also showed a relatively even distribution as compared to the rest with representations in almost all of the classes. No girth class showing very high densities.

4.3.5 The correlations between the proportional abundances of trees and saplings of Iyerpadi (ρ= 0.308, N=52, p=0.025), Pannimedu (ρ= 0.425, N=50, p=0.002) and Puduthotam (ρ= 0.515, N=30, p= 0.003) were very weakly positive though significant. Andiparai also showed a weak positive correlation (ρ= 0.276, N=47, p=0.060) which was insignificant. On the other hand, Varattuparai 1c showed a weak negative correlation (ρ= -0.349, N=50, p=0.012) along with Varattuparai 4 (ρ= -0.396, N=26, p= 0.045) (Fig. 6.a –f).

4.4 VEGETATION COMPOSITION

4.4.1 A total of 2446 trees and 4163 saplings were enumerated across 38 families and 74 genera. The total number of identified species was 135. (Appendix. 1).

4.4.2 The total endemic species richness was 37. Iyerpadi and Pannimedu showed the highest richness in endemic species (21) while Puduthotam with 9 endemics was the lowest. (Appendix. 2).

4.4.3 The generic richness of rainforest trees was highest in Iyerpadi (46) and lowest in Varattuparai 4 (14). The generic richness of non rainforest trees was highest in Puduthotam (3) while Iyerpadi and Pannimedu had no non rainforest trees (Table 5). The generic richness of rainforest saplings was highest in Iyerpadi (43) and lowest in Varattuparai 4 (12). However, the generic richness of non rainforest saplings was highest in Varattuparai 4 (3) and lowest in Iyerpadi which had no non rainforest saplings (Table 5).

4.4.4 The mean generic richness of rainforest trees was highest in Iyerpadi (Mean=10.76, SE ± 0.69) and lowest in Puduthotam (Mean= 2.72, SE ± 0.227, Table 5). The mean generic richness of rainforest saplings was highest in Iyerpadi (Mean=13.48, SE ± 0.66) and lowest in Puduthotam (Mean= 3.72, SE ± 0.34, Table 5).

4.4.5 Fragments showed significant differences in generic richness of rainforest trees ($KW\chi^2$=70.341, df=5, p<0.01) and rainforest saplings ($KW\chi^2$=73.582, df=5, p<0.01)

4.4.6 The pattern of the rank abundance graphs show that abundance in Puduthotam are most un-evenly distributed, and were more even in relatively un-disturbed fragments (Fig. 7a & b). Rank abundance plots for trees showed that the top three dominant genera in Andiparai were *Hydnocarpus* (13.86%), *Cullenia* (11.34%) and *Croton* (10.08%), *Litsea* (9.95%), *Gomphandra* (7.03%) and *Hydnocarpus* (5.58%) in Iyerpadi, *Dimocarpus* (13.1%), *Cullenia* (10.16%) and *Agrostistachys* (8.55%) in Pannimedu, *Maesopsos* (61.11%), *Macaranga* (12.15%) and *Maesa* (11.11%) in Puduthotam, *Maesopsos* (19.37%), *Acronychia* (14.37%) and *Maesa* (13.75%) in Varattuparai 1c, unidentified non rainforest species (32%), *Ficus* (12%) and *Macaranga, Maesopsos and Mangifera* each having a relative abundance of (8%) in Varattuparai 4 (Appendix. 3A).

The rank abundance plots for saplings showed the top three dominant genera in Andiparai were *Meiogyne* (15.3%), *Aglaia* (10.9% and *Mesua* (8.1%), *Litsea*

(25.4%), *Dimocarpus* (6.5%) and *Croton* (6.2%) in Iyerpadi, *Croton* (19.4%), Syzigium (18.2%) and *Villebrunea* (11.3%) in Pannimedu, *Dimocarpus* (39.6%), *Maesa* (32.07%) and *Mesua* (6.1%) in Puduthotam, Coffee (18.79%), *Dimocarpus* (15.03%) and *Maesa* (9.77%) in Varattuparai 1c, unidentified non rainforest species (29.16%), *Maesa* (18.75%) and Coffee (14.5%) in Varattuparai 4 (Appendix 3B).

4.4.7 Rarefaction curves for rainforest trees showed that Iyerpadi had the highest rate of increase in genera and Puduthotam the lowest (Fig. 8a). The same trend was also observed for the rarefaction curves for rainforest saplings (Fig. 8b). The rarefaction curves for trees and saplings showed an asymptote only for Iyerpadi, Pannimedu, Andiparai and Puduthotam. .

4.4.8 The cluster analysis of densities/ha of genera of trees showed the first cluster being formed by Andiparai, and Iyerpadi to which joins Pannimedu. Puduthotam and Varattuparai 4 formed the last cluster while varattuparai 1c showed an intermediate position (Fig. 9a). The fragments on average were dissimilar in their generic composition by 72.48%. Iyerpadi and Varattuparai 4 were 85.61% dissimilar in their generic composition of trees. However, the two least different fragments, Iyerpadi and Andiparai differed in their generic composition by 52.75% (Fig. 9a).

The cluster analysis for saplings show Pannimedu and Varattuparai 1c forming the first cluster. Iyerpadi and Andiparai form the last cluster (Fig. 9b). Fragments were different in their generic composition on average by 74.13%.

Iyerpadi and Varattuparai 4 were different in their generic composition by 88.96% making them the most dissimilar fragments. The minimum dissimilarity recorded was 59.56% between Pannimedu and Varattuparai 1c.

4.5 RELATIONSHIPS BETWEEN FRAGMENT CHARACTERISTICS, DISTURBANCE, VEGETATION COMPOSITION.

4.5.1 Relationships between fragment characteristics

Area of fragments showed a negative relationship with the time since isolation (ρ= -0.638, p=0.173). On the other hand, area showed a positive relationship with altitude range (ρ= 0.754, p=0.084).

4.5.2 Relationships between fragment characteristics and disturbance

It was found that factor 1 of disturbance showed a significant positive relationship with time since isolation (ρ= 0.986, N=6, p<0.01). A negative relationship between area and factor 1 of disturbance was also observed (ρ= -0.657, N=6, p=0.156)

4.5.3 Relationships between fragment characteristics, disturbance and generic richness

Rain forest tree generic richness showed a negative correlation with factor 1 of disturbance (ρ= -0.771, N=6, p=0.072), factor 2 of disturbance (ρ= –0.371, N=6, p=0.468) (Fig. 13a & 12a), and time since isolation (ρ= -0.696, N=6, p=0.125). It also showed a weak positive correlation with area (ρ=0.543, N=6, p=0.266), median altitude (ρ=0.464, N=6, p=0.354), altitude range (ρ=0.638, N=6, p=0.173). Generic richness of rainforest saplings showed a significant negative correlation with factor 1 of disturbance (ρ= -0.886, N=6, p=0.017) (Fig. 10b) and time since isolation (ρ=-0.841, N=6, p=0.036) (Fig 13b) . It also showed a negative correlation with factor two of disturbance (ρ= -0.429, N=6, p=0.397) (Fig. 11b). There were positive correlations with area (ρ= 0.714, N=6, p=0.11) (Fig. 12b), median altitude (ρ= 0.667, N=6, p=0.148) and altitude range (ρ=0.783, N=6, p=0.066) (Fig. 14b).

The linear multiple regression of generic richness of rainforest trees with area, altitude range, time since isolation and the 2 factors of disturbance selected a final model which showed the two factors of disturbance to be the principal predictors (R^2=0.836, adjusted R^2= 0.727, F=7.646, df=5, p=0.066). The standardised coeffecients for the two predictors were (Dist Factor 1=-0.730, p=0.052, Dist Factor 2= -0.551, p=0.100). However, the final model selected three predictors for sapling generic richness which were the two factors of disturbance and altitude range (R^2=0.998, adjusted R^2=0.996, F=420.380, df=5, p<.01). The standardised coefficients for the three predictors were (Dist Factor 1=-1.076, p=0.001, Dist Factor 2=-5.01, p=0.003, altitude range=-0.280, p=0.022).

4.5.4 Relationships between fragment characteristics, disturbance and vegetation composition

The Mantel's randomisation test between dissimilarity matrices of tree generic richness, sapling generic richness and dissimilarity matrices of area, time since isolation, disturbance and altitude selected disturbance as a significant determinant of floristic composition of rainforest trees (F=11.94, p< 0.01 and saplings (F=11.87, p< 0.05) (Table 6a & b).

Table 3 - Factor Analysis of Disturbance Variables

	Initial Eigen Value		
Component	Total	% of Variance	Cumulative %
1	4.576	50.845	50.845
2	3.551	39.456	90.301

Rotated Component Matrix		
	Component 1	Component 2
Non rainforest Trees	0.491	**0.856**
Non rainforest Saplings	**0.842**	-0.150
Lopped saplings	**0.845**	-0.361
Cut trees	-0.273	**0.858**
Lopped trees	**0.995**	-0.00855
Average percentage of canopy openness	**0.866**	0.400
Non rainforest seedlings	0.122	**0.964**
Average percentage ground cover of weedy herbs	-0.09231	**0.961**
Percentage frequency of presence of weedy shrubs	**0.966**	0.241

Table 4 - Density and mean abundance of trees and saplings in the fragments

F.NAME	density/ ha RF trees	Density/ ha of NRF trees	density/ ha of RF sapling	density/ ha of NRF sapling	Mean Abundance of RF tree/plot	Std error	Mean abundance of RF sapling/plot	Std error
Andiparai	699	1	7608	32	27.96	1.94	38.04	3.11
Iyerpadi	549	0	10872	0	21.96	1.82	54	3.37
Pannimedu	618	0	5208	64	24.72	1.25	26.04	1.92
Puduthotam	178	179	6528	176	7.12	0.56	32.64	3.28
varattuparai 1c	433.33	88.88	4911.1	1644.4	17.22	2.1	24.55	2.7
varattuparai 4	200	83.33	2266.7	1533.3	8	2.6	11.33	4.17

Table 5 - Generic richness of trees and saplings in the fragments

F.NAME	Generic richness of RF trees	Generic richness of NRF trees	Generic richness of RF sapling	Generic richness of NRF sapling	Mean generic richness of RF trees/plot	Std error	Mean generi richness of RF sapling/plot	Std error
Andiparai	36	1	37	1	6	0.36	6.56	0.54
Iyerpadi	46	0	43	0	10.76	0.69	13.48	0.66
Pannimedu	40	0	38	1	9.52	0.569	7.76	0.38
Puduthotam	16	3	19	2	2.72	0.227	3.72	0.34
Varattuparai 1c	38	2	26	2	9.22	1.19	8.44	0.86
Varattuparai 4	14	2	12	3	5.33	1.4	4.33	1.45

Table 6a - Regression of Tree Generic composition with environmental Factors.

(1-Altitude, 2-Area, 3-Disturbance, 4-Isolation time)

REGRESSION FOR OBSERVED DATA

```
Total SS =   0.1295E+00

 Variable          Coef          t      Extra SS         F
==================================================
         0   0.6274E+00
         1  -0.8942E-01    -0.80   0.3341E-03     0.07
         2   0.1547E+00     1.23   0.1907E-01     3.83
         3   0.2028E+00     3.47   0.5953E-01    11.94
         4  -0.2144E-01    -0.38   0.7046E-03     0.14
==================================================

Error SS =   0.4986E-01, F =      3.99
```

Significance of t-values (P1, % of absolute randomization values greater than or equal to observed absolute t), and significance of F-values for extra sums of squares when variables are added in order (P2, % of randomization values greater than or equal to observed F).One-sided significance levels for t-values are half of those shown here providing that the observed coefficient has the correct sign for the alternative hypothesis.

```
           b(1)    b(2)    b(3)    b(4)
P1 (%)    43.79   21.65    0.68   71.64
P2 (%)    80.48    8.70    0.49   71.64
```

Significance for overall F (%) =   3.49

Table 6b - Regression of Sapling Generic composition with environmental Factors.

(1-Altitude, 2-Area, 3-Disturbance, 4-Isolation time)

REGRESSION FOR OBSERVED DATA

Total SS = 0.1324E+00

Variable	Coef	t	Extra SS	F
0	0.5468E+00			
1	0.1529E+00	1.40	0.1334E-01	2.81
2	-0.7727E-01	-0.63	0.1957E-02	0.41
3	0.1811E+00	3.18	0.5636E-01	11.87
4	0.9303E-01	1.67	0.1326E-01	2.79

Error SS = 0.4750E-01, F = 4.47

Significance of t-values (P1, % of absolute randomization values greater than or equal to observed absolute t), and significance of F-values for extra sums of squares when variables are added in order (P2, % of randomization values greater than or equal to observed F). One-sided significance levels for t-values are half of those shown here providing that the observed coefficient has the correct sign for the alternative hypothesis.

	b(1)	b(2)	b(3)	b(4)
P1 (%)	17.76	55.20	1.31	13.23
P2 (%)	11.84	51.54	1.07	13.23

Significance for overall F (%) = 2.85

Figure 1 – A schematic representation of the sampling design and the placement of quadrats

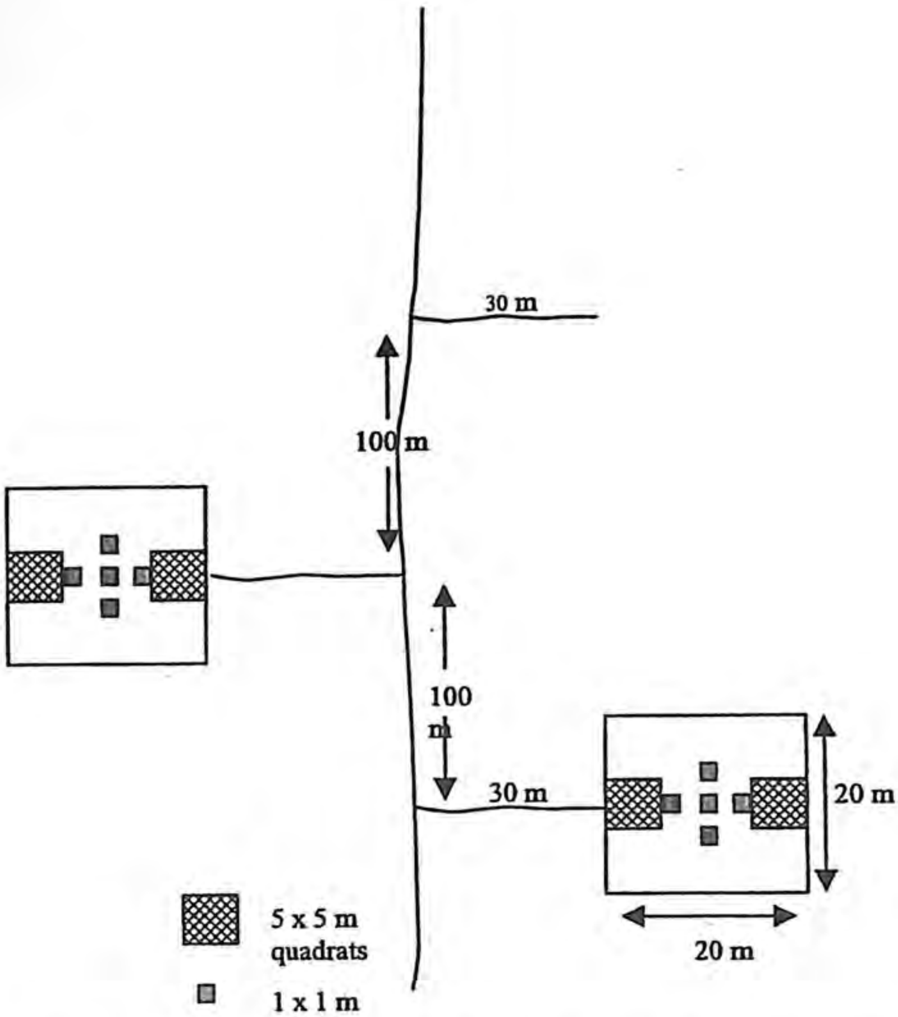


Figure 2 – Dendrogram showing similarity in size ($\log_{10}$ Area) between fragments.

Dendrogram using Average Linkage (Between Groups)

```
                    Rescaled Distance Cluster Combine

   C A S E      0         5        10        15        20        25
  Label     Num  +---------+---------+---------+---------+---------+

  PN          3   -+
  PU          4   -+----------------+
  AN          1   -+                +-------------------------------+
  V1C         5   ---+--------------+                               I
  V4          6   ---+                                              I
  IP          2   --------------------------------------------------+
```

Figure 3 – Dendrogram showing similarity in time since isolation.

Dendrogram using Single Linkage

```
                         Rescaled Distance Cluster Combine

    C A S E      0         5        10        15        20        25
  Label     Num  +---------+---------+---------+---------+---------+

  V1C         5   -+-------------+
  V4          6   -+             +-------------------+
  PU          4   ---------------+                   +-------------+
  AN          1   -----------------------------------+             I
  IP          2   ---------+---------------------------------------+
  PN          3   ---------+
```

Figure 4 – Canopy openess across fragments

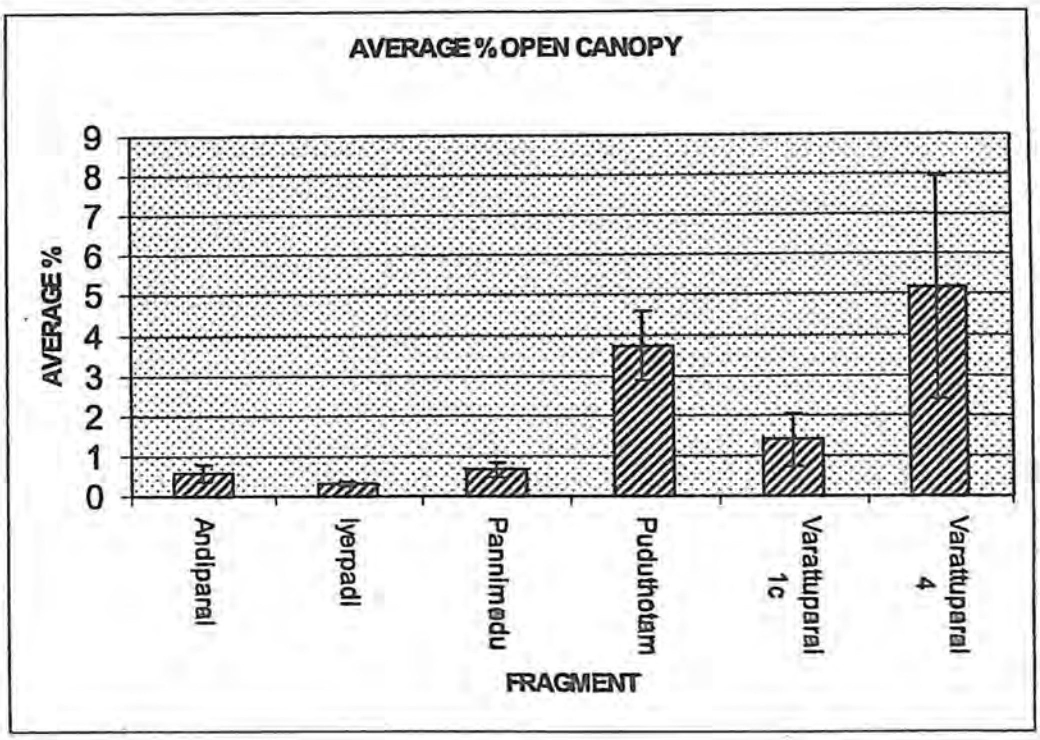


Figure 5 – Relationship of fragments with disturbance factors

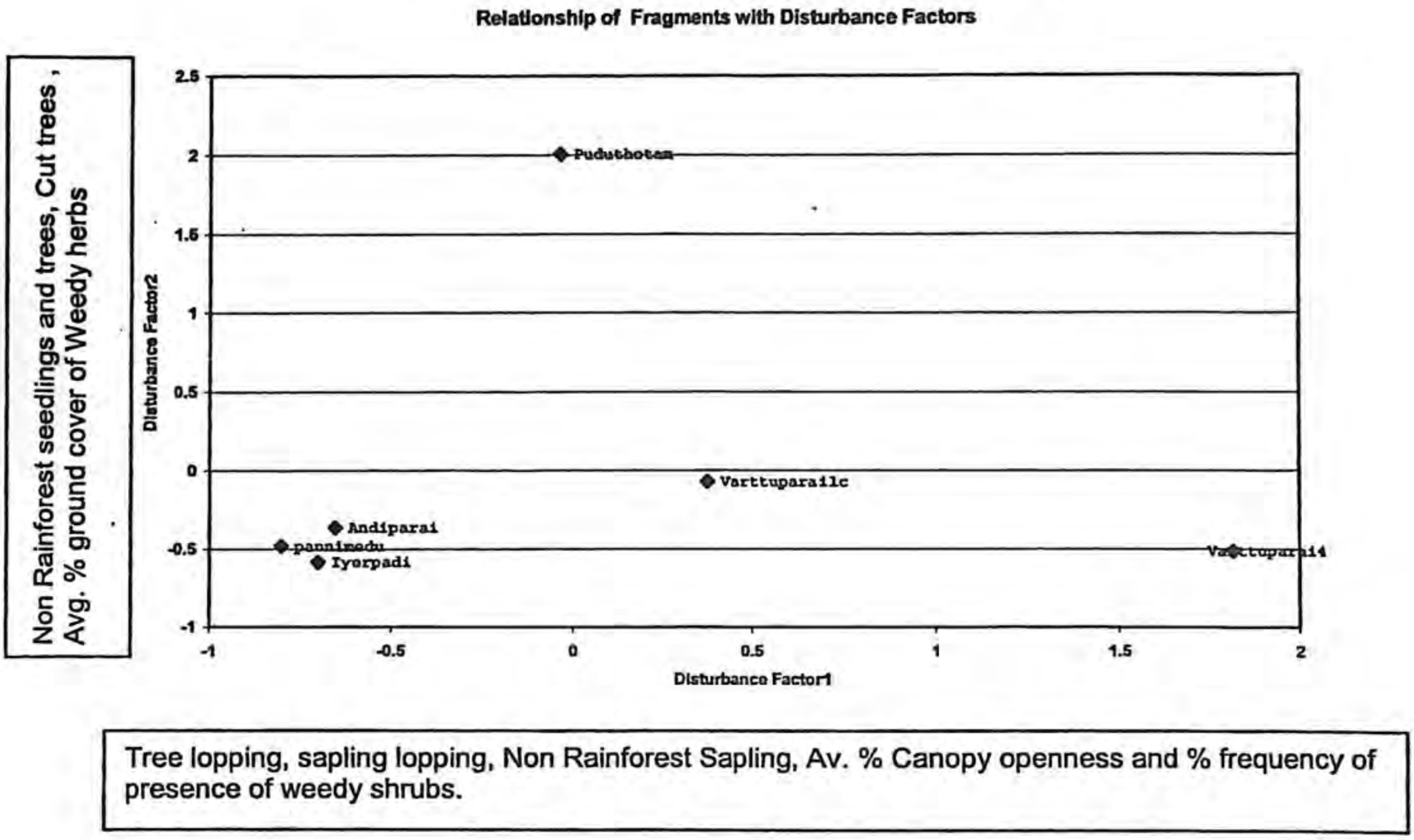


Figure 6a – Correlation between sapling and tree composition – Andiparai

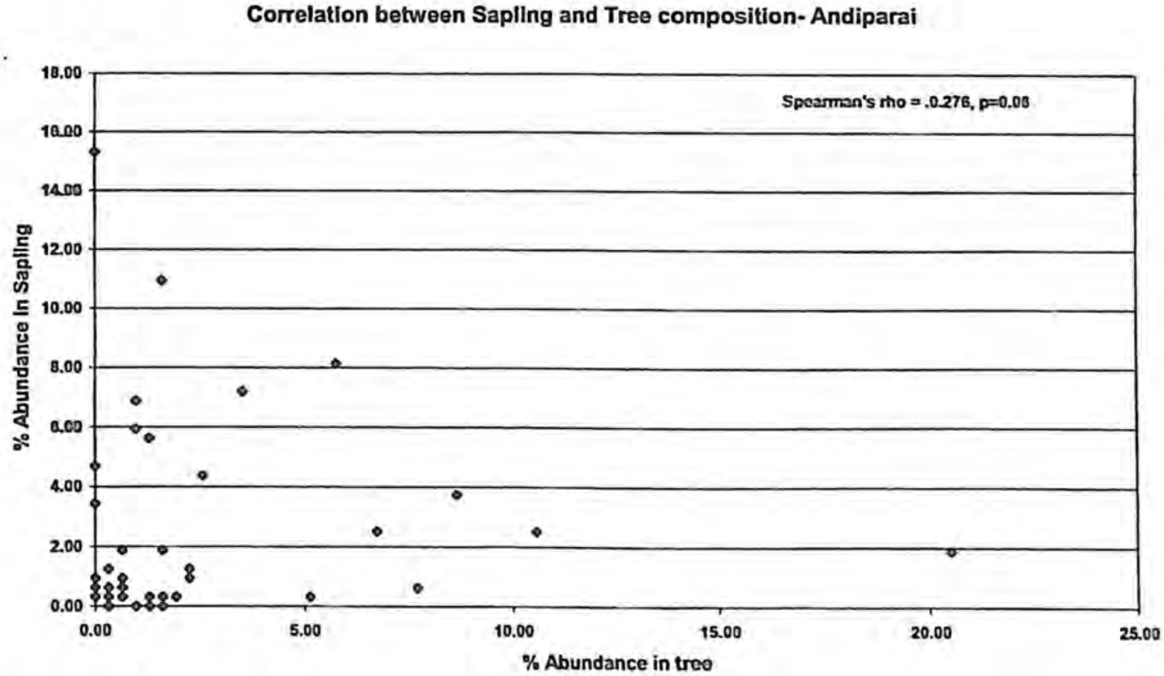


Figure 6b – Correlation between sapling and tree composition - Iyerpadi

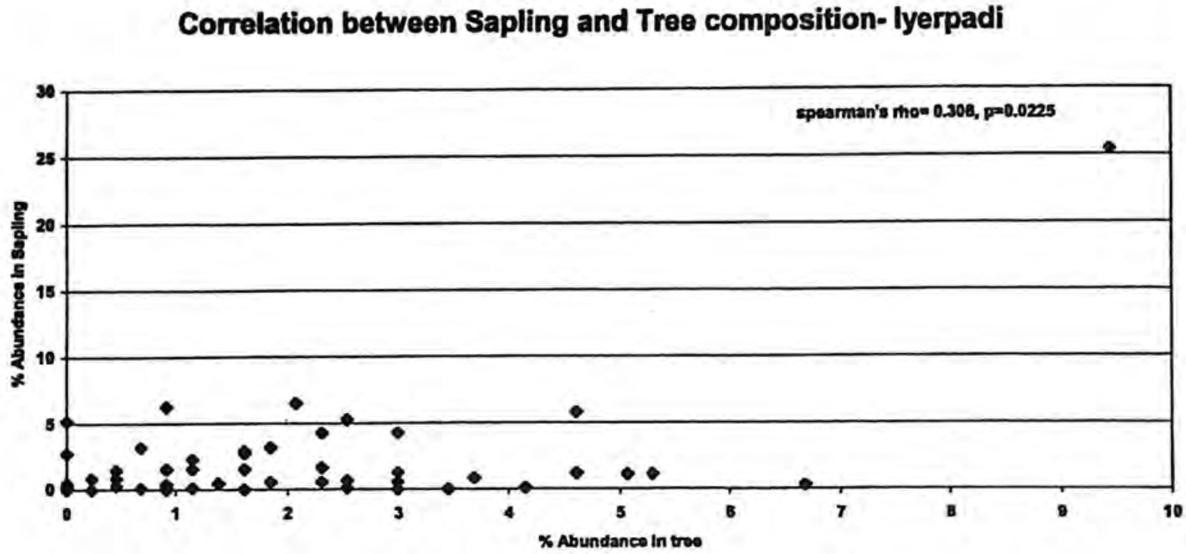


Figure 6c – Correlation between sapling and tree composition - Pannimedu

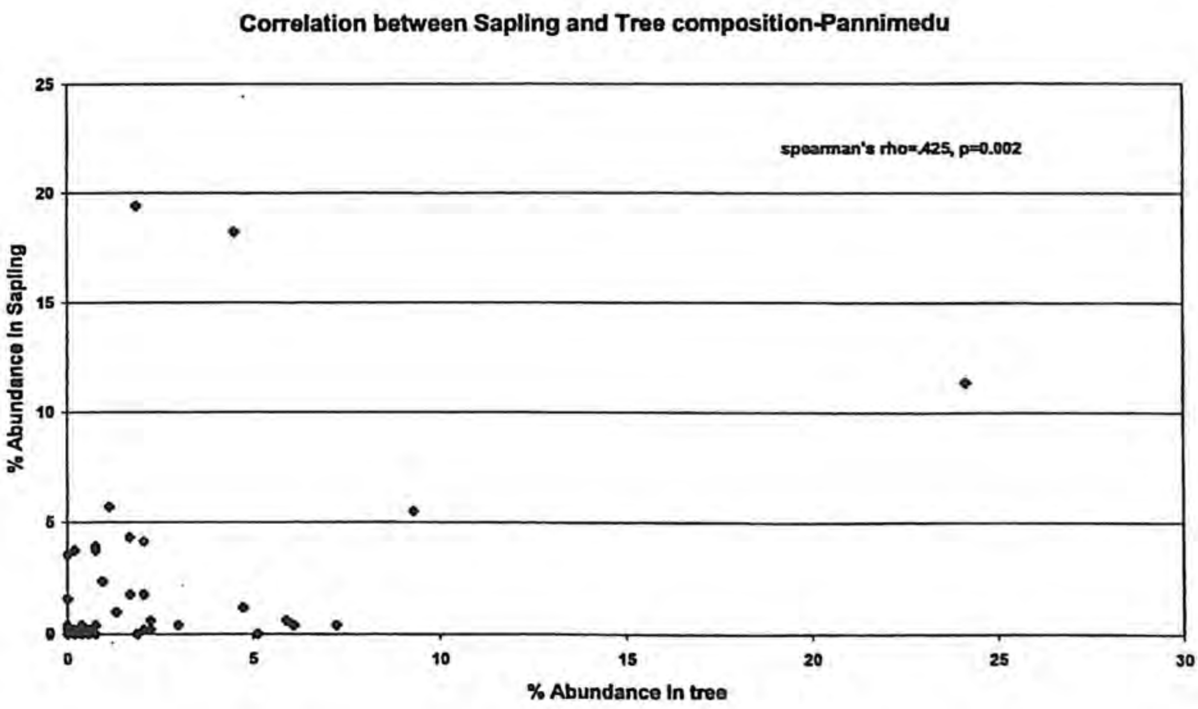


Figure 6d – Correlation between sapling and tree composition – Puduthotam

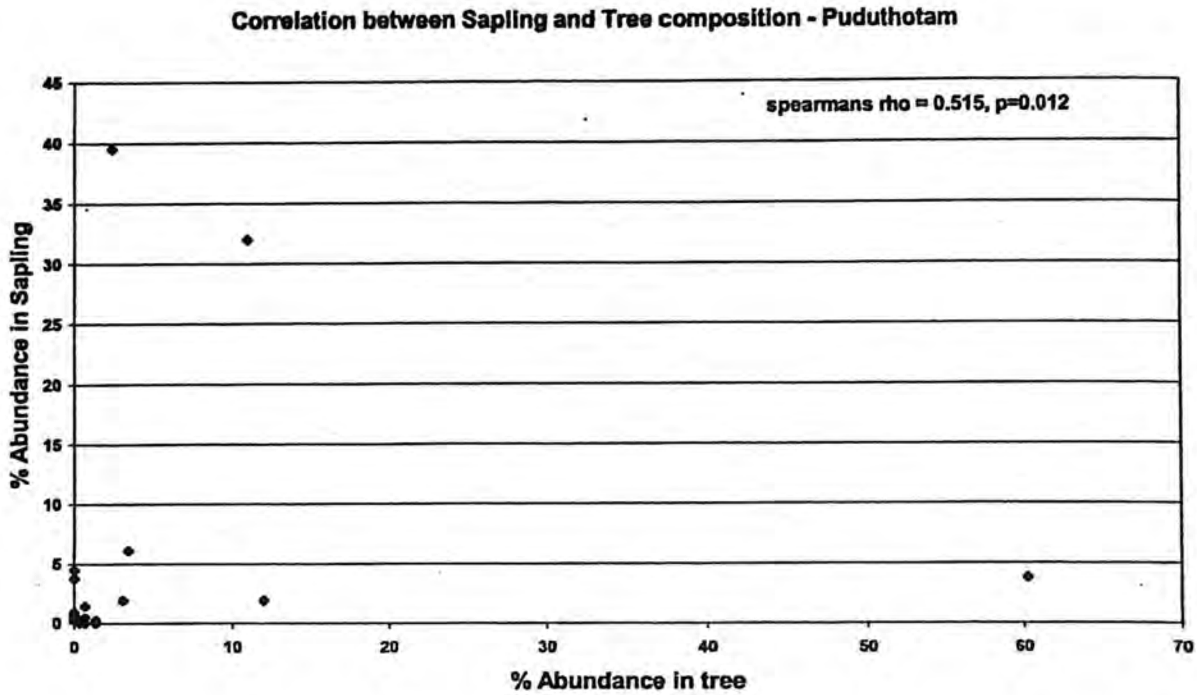


Figure 6e – Correlation between sapling and tree composition – Varattuparai 1C

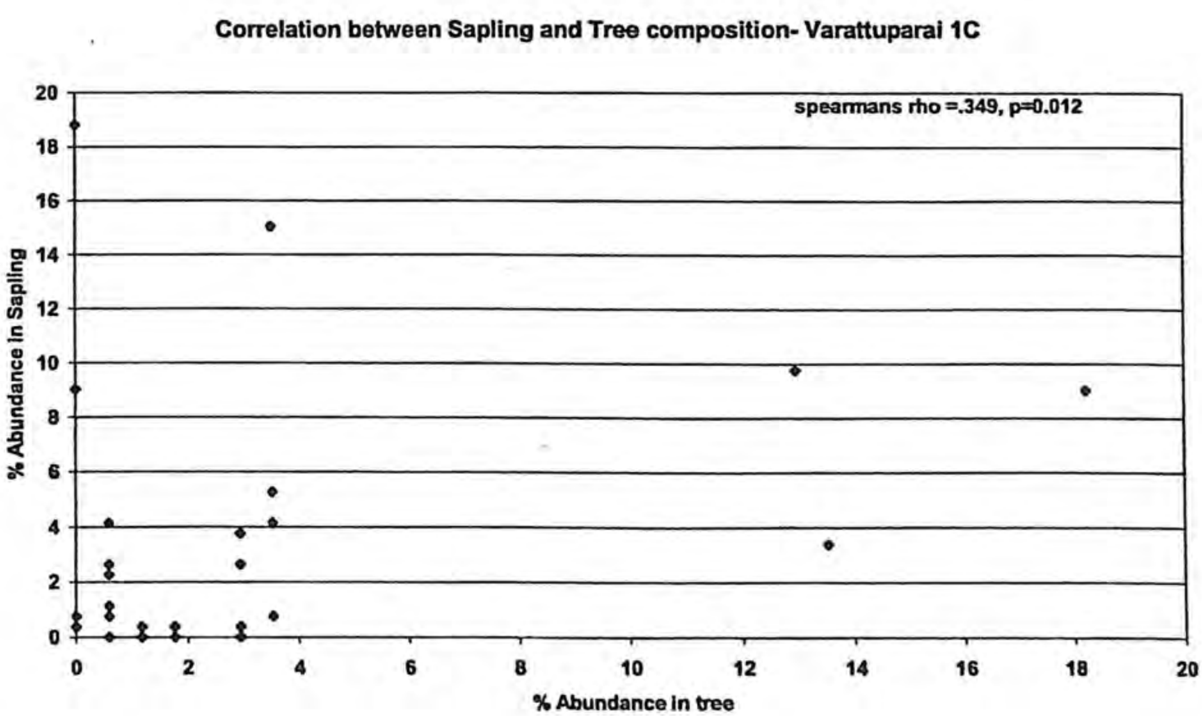


Figure 6f – Correlation between sapling and tree composition – Varattuparai 4

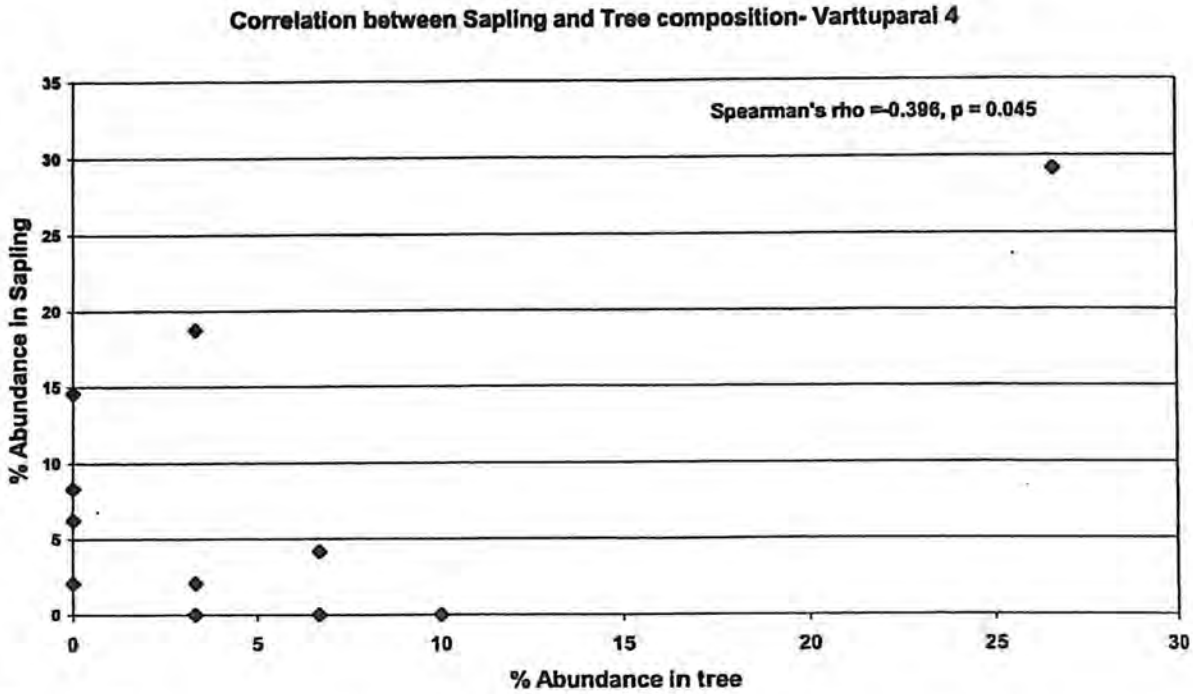


Figure 7a – Tree genera rank abundance

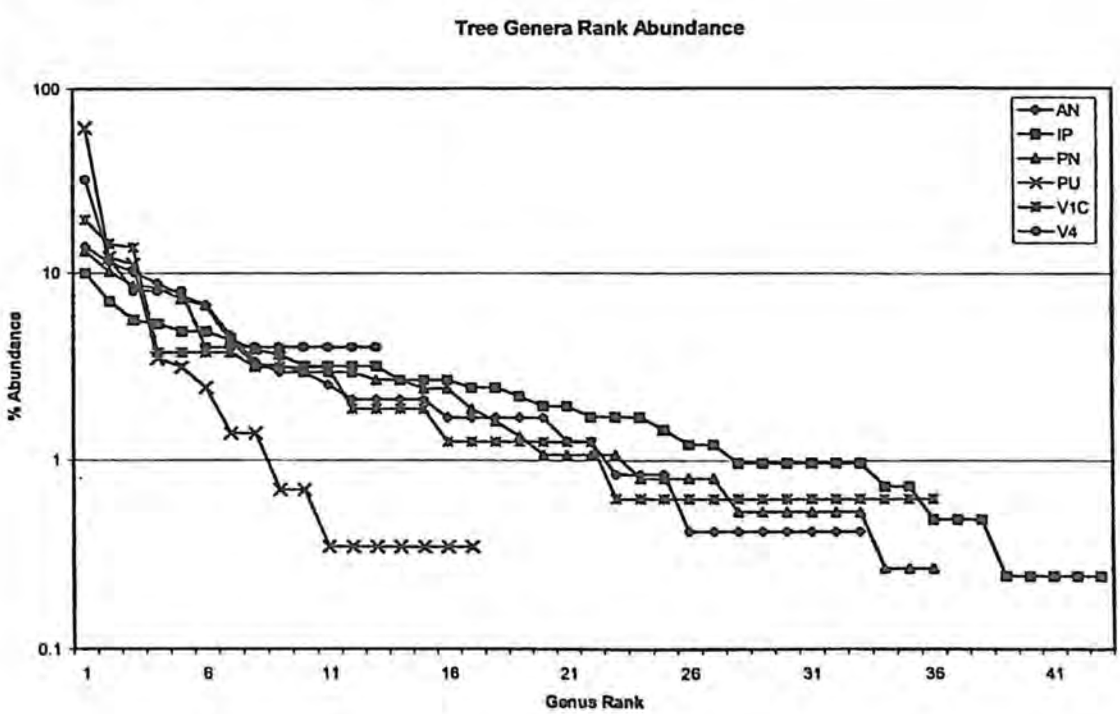


Figure 7b – Sapling genera rank abundance

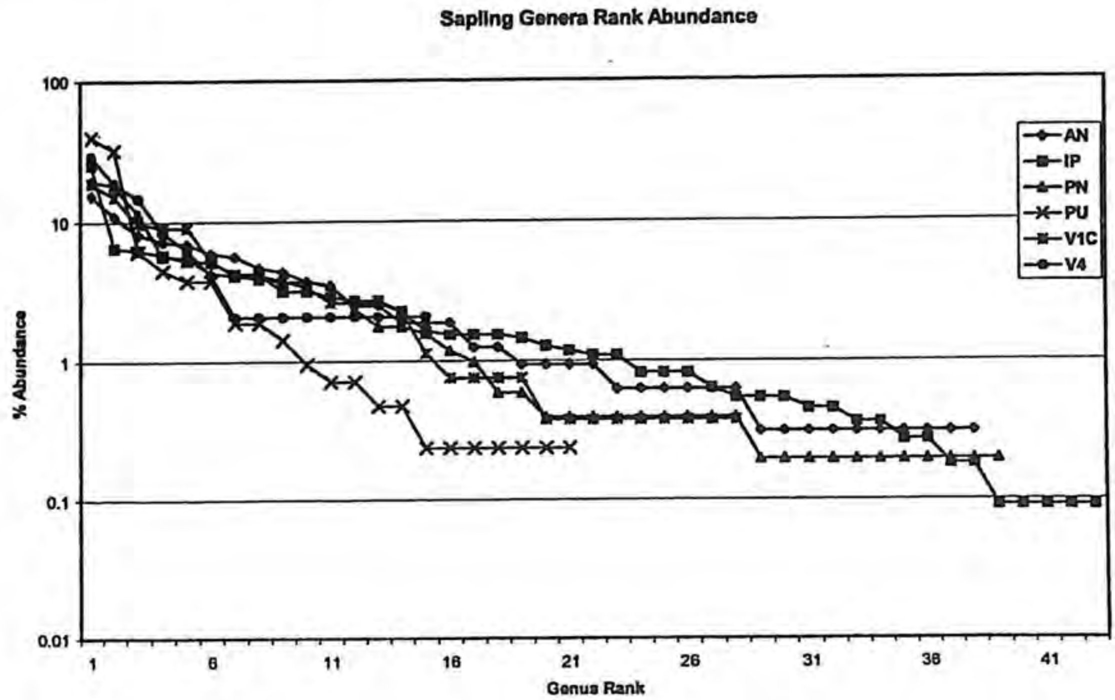


Figure 8a – Rarefaction curves for Rainforest trees

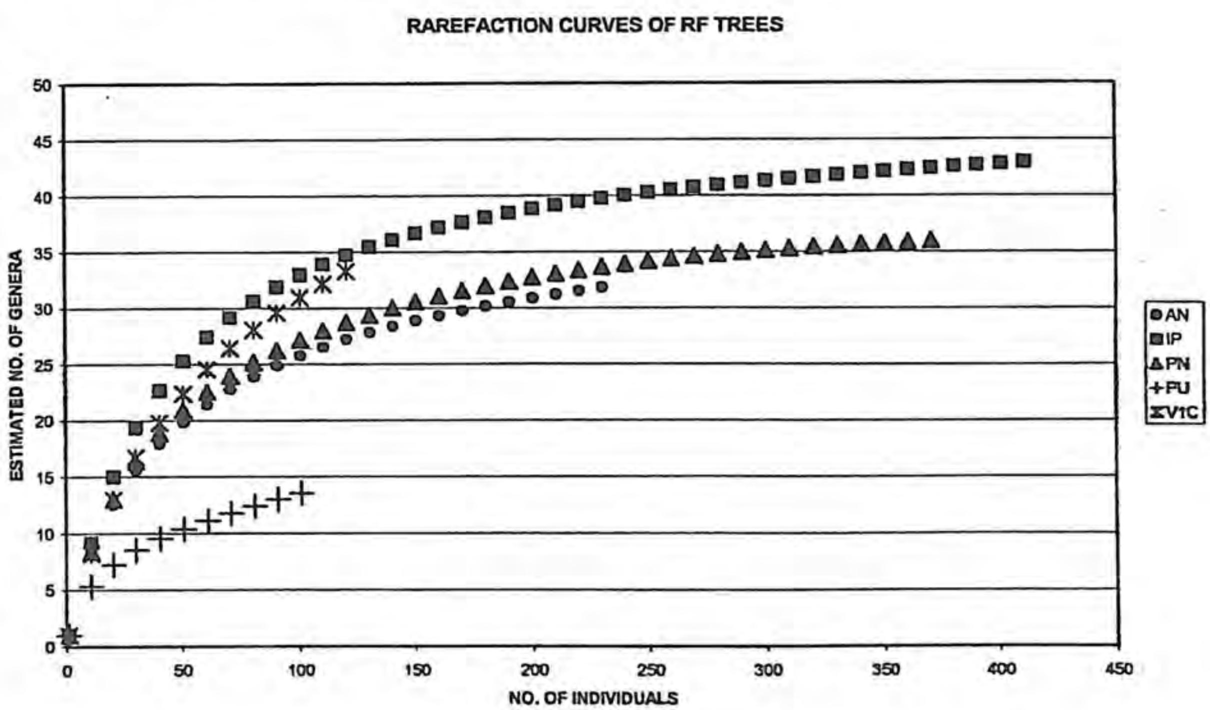


Figure 8b – Rarefaction curves for Rainforest saplings

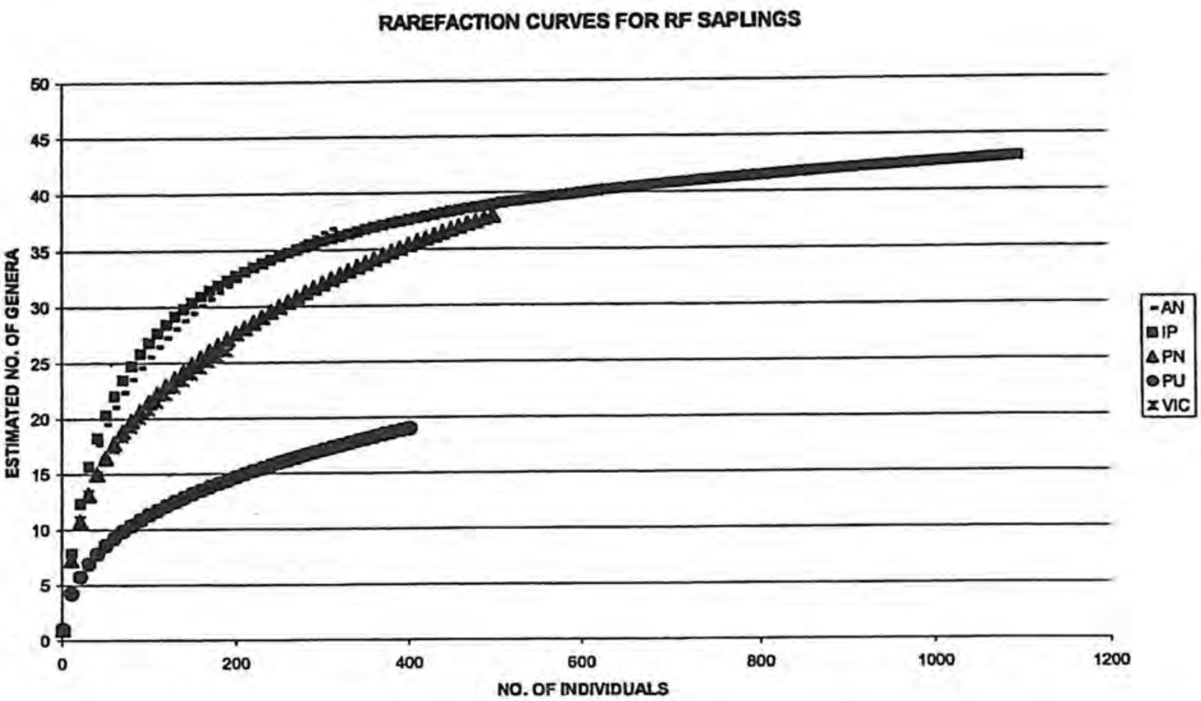


Figure 9a - Dendrogram showing similarity in tree genera among the fragments

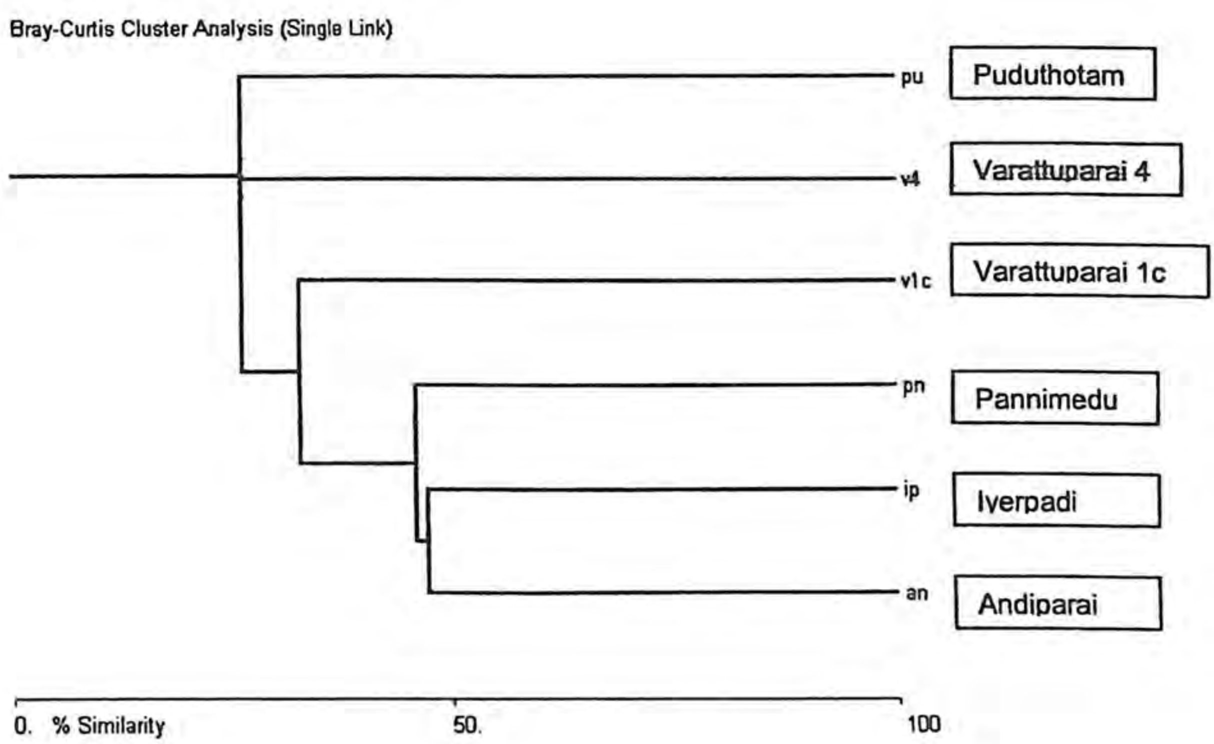


Figure 9b - Dendrogram showing similarity in sapling genera among the fragments

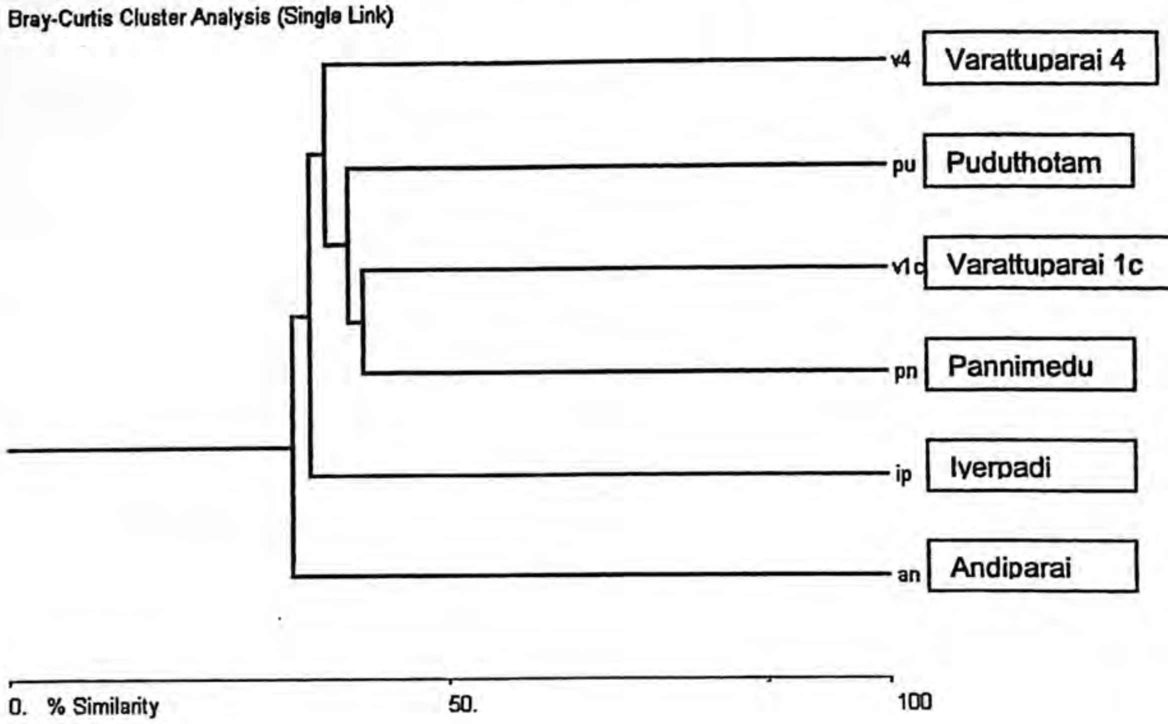


Figure 10a – Relationship of rainforest tree generic richness with disturbance Factor1

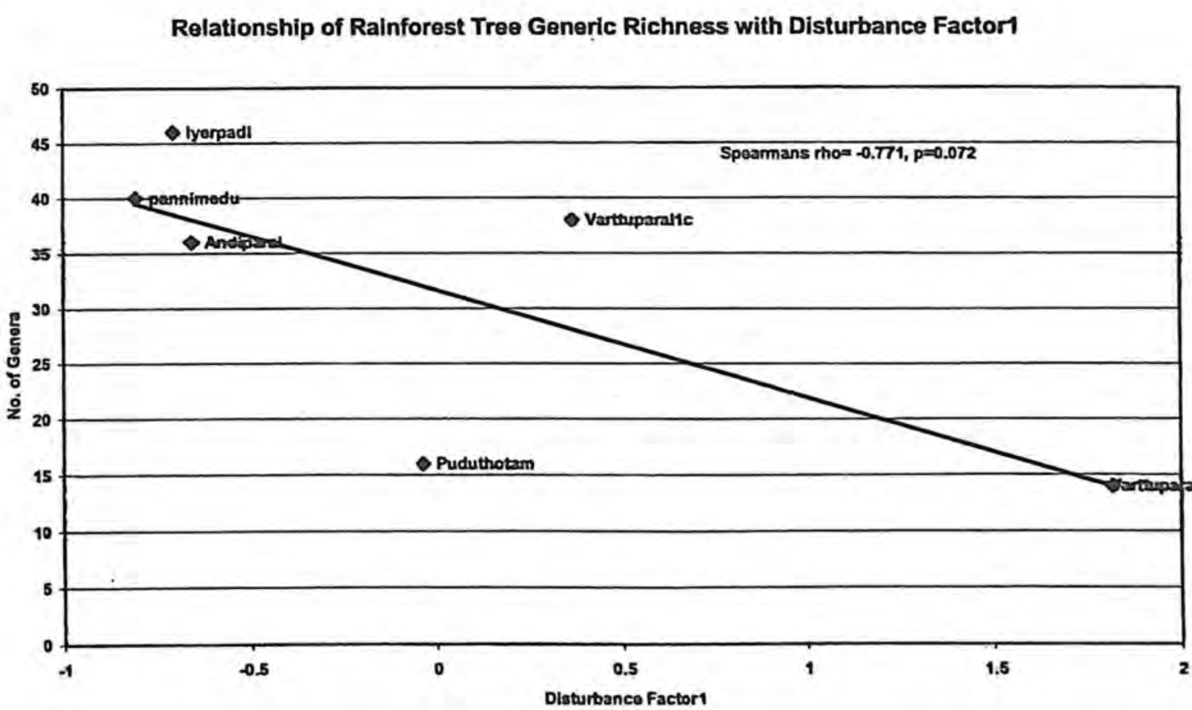


Figure 10b – Relationship of Rainforest Sapling Generic Richness with Disturbance factor 1

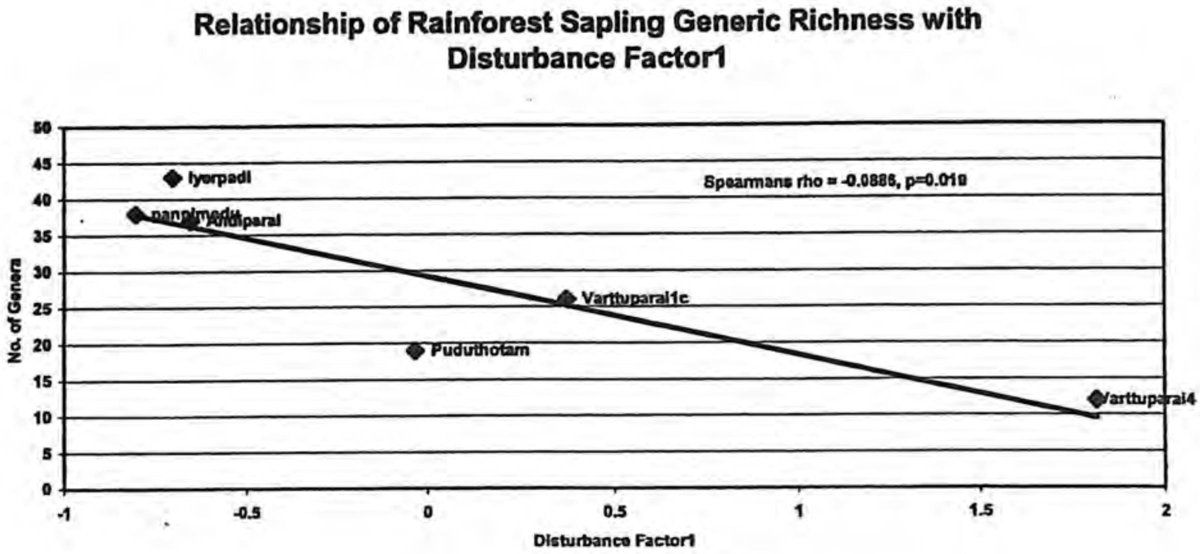


Figure 11a – Relationship of Rainforest Tree Generic Richness with Disturbance factor 2

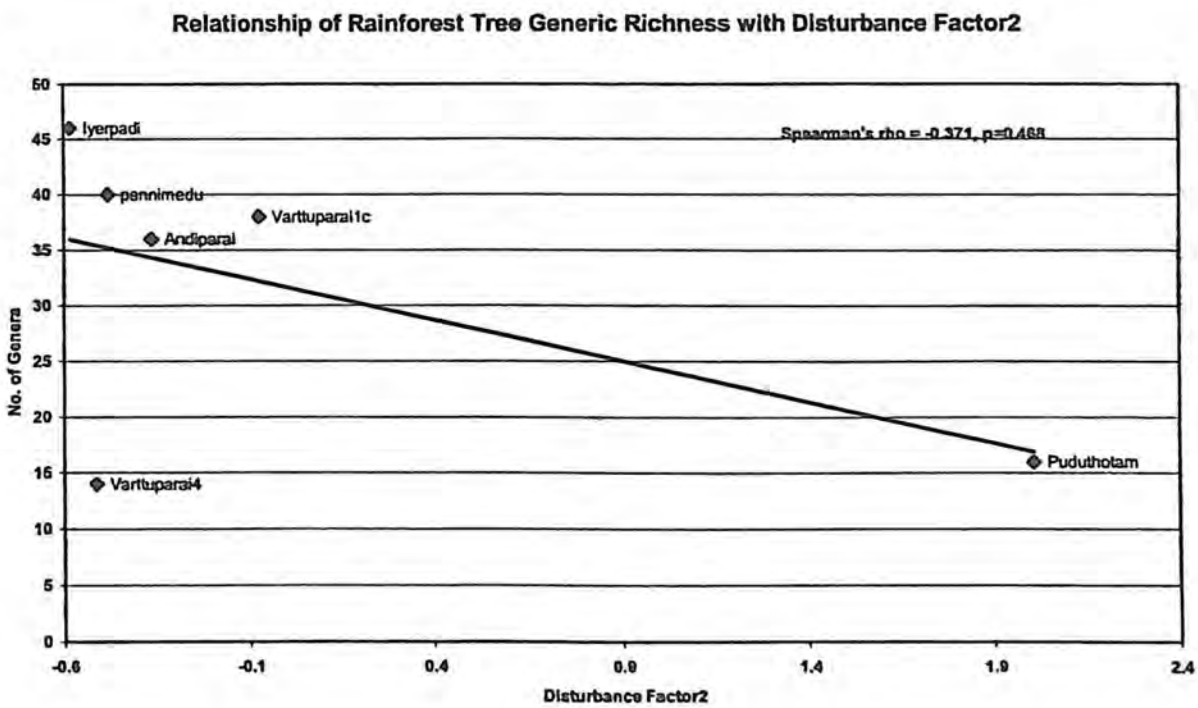


Figure 11a – Relationship of Rainforest Sapling Generic Richness with Disturbance factor 2

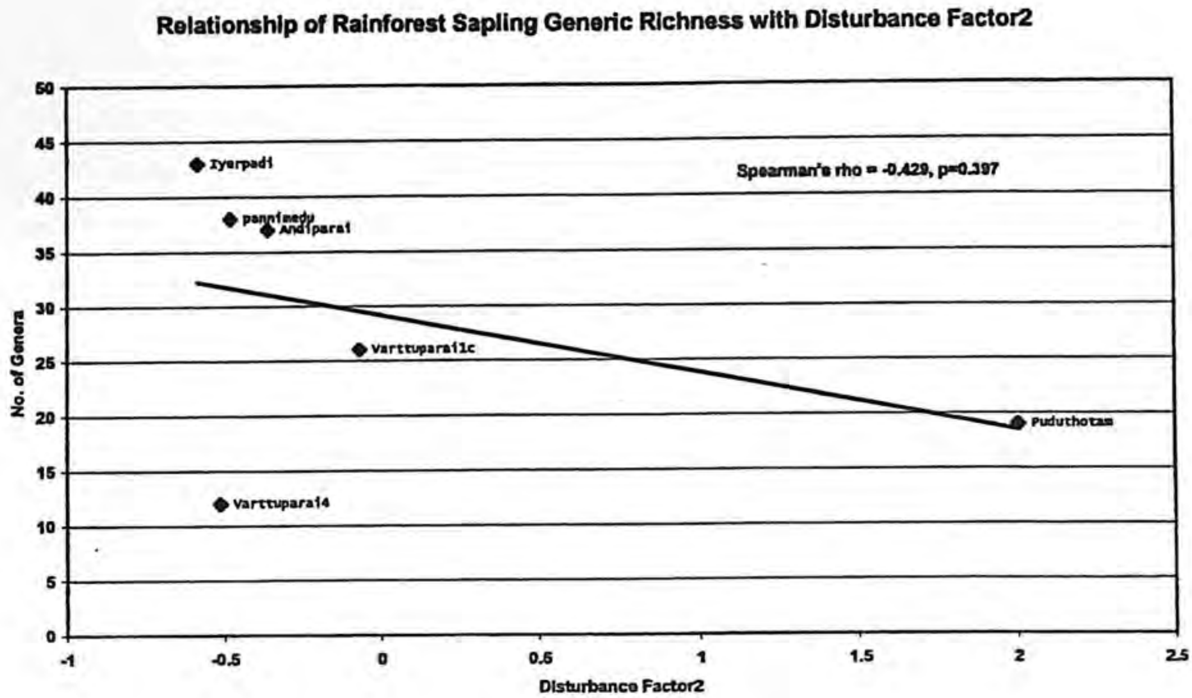


Figure 12a – Relationship of Rainforest Tree Generic Richness with Area

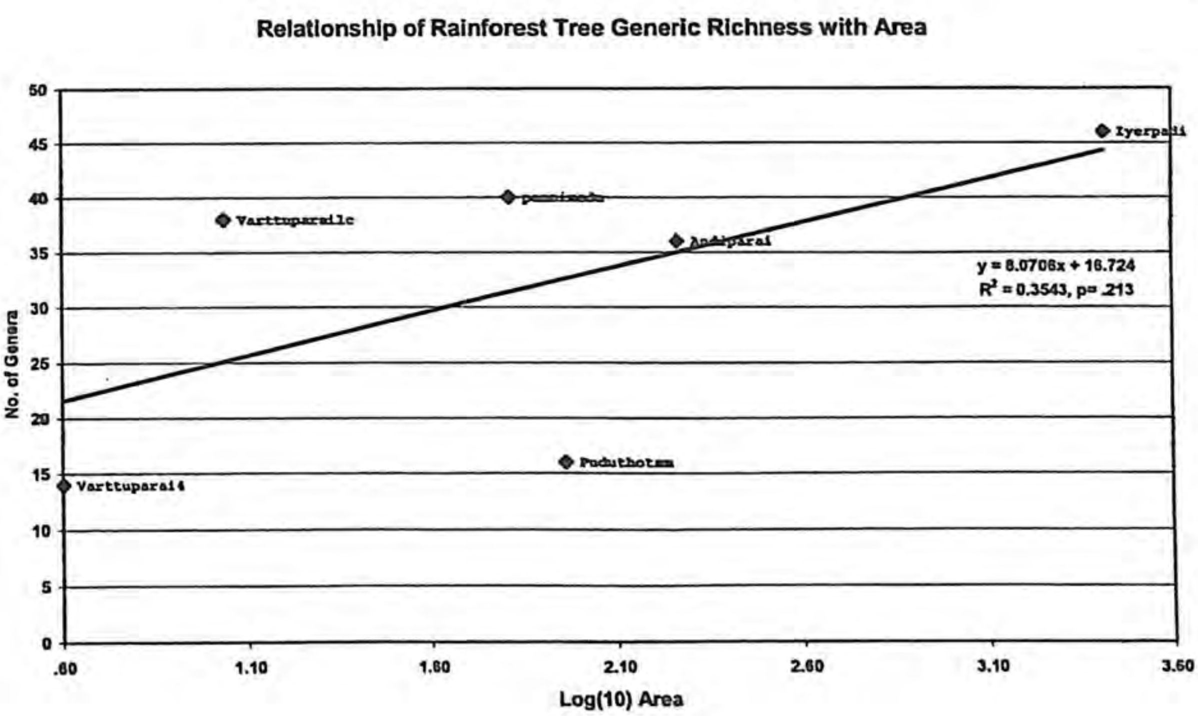


Figure 12b – Relationship of Rainforest Sapling with area

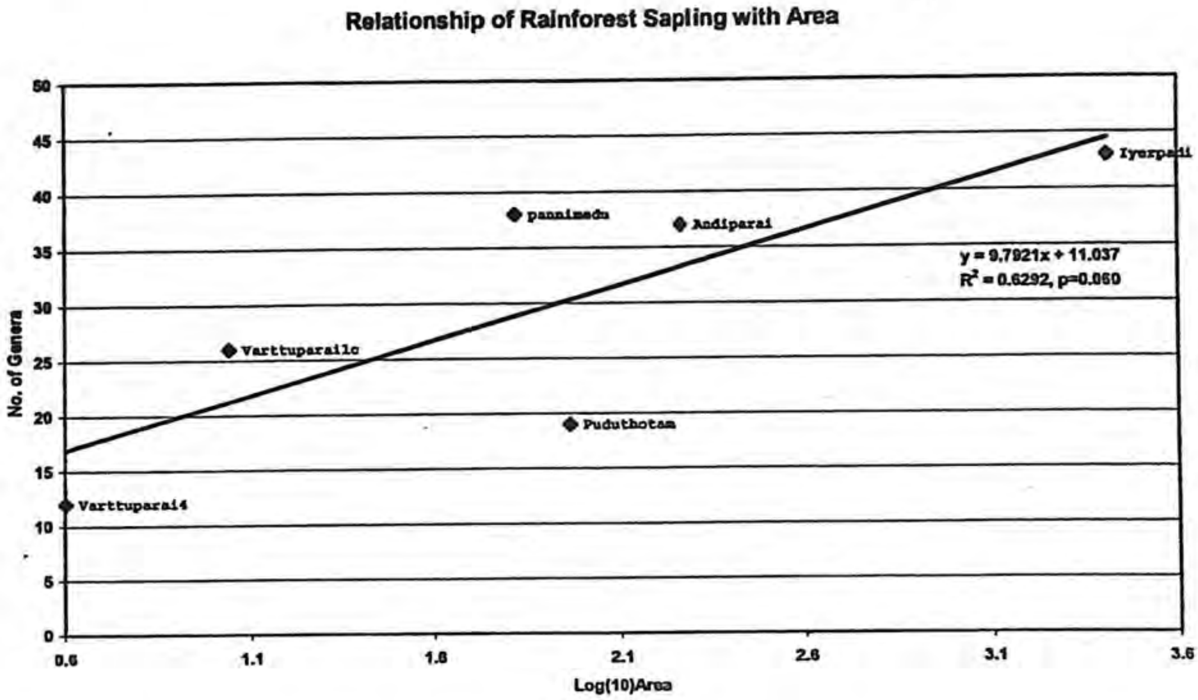


Figure 13a – Relationship of Rainforest Tree Generic Richness with isolation time of fragment

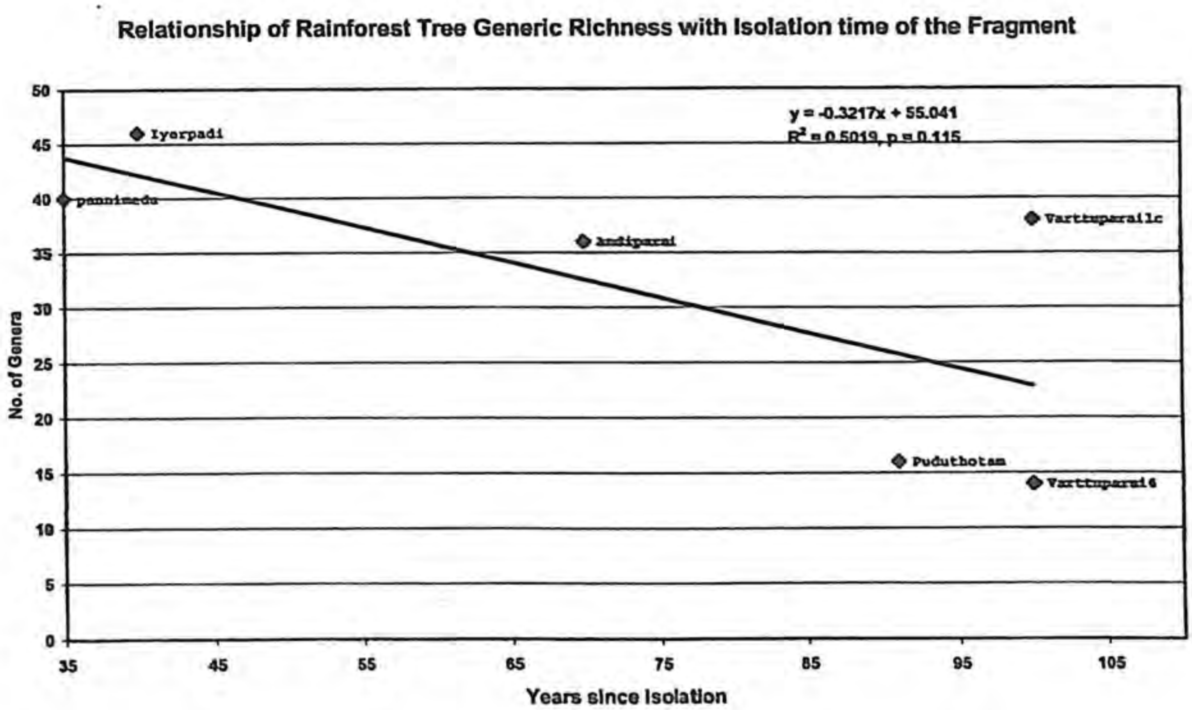


Figure 13b – Relationship of Rainforest Sapling Generic Richness with isolation time of fragment

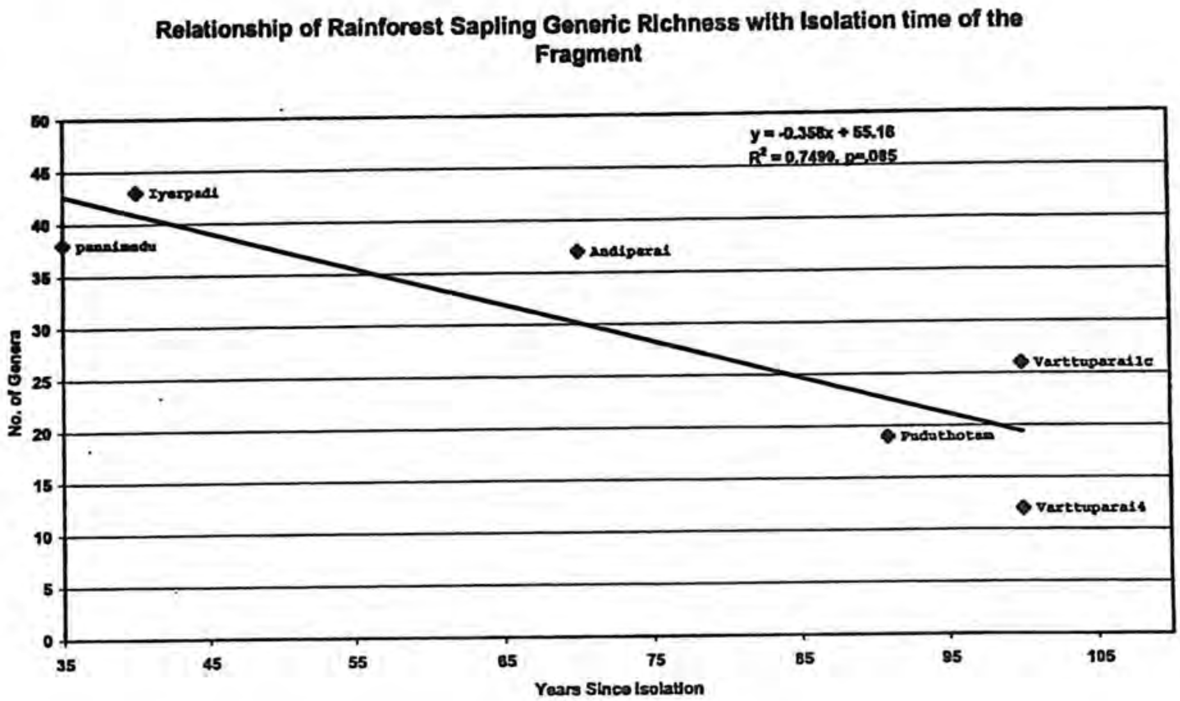


Figure 14a – Relationship of Rainforest Tree Generic Richness with Altitude

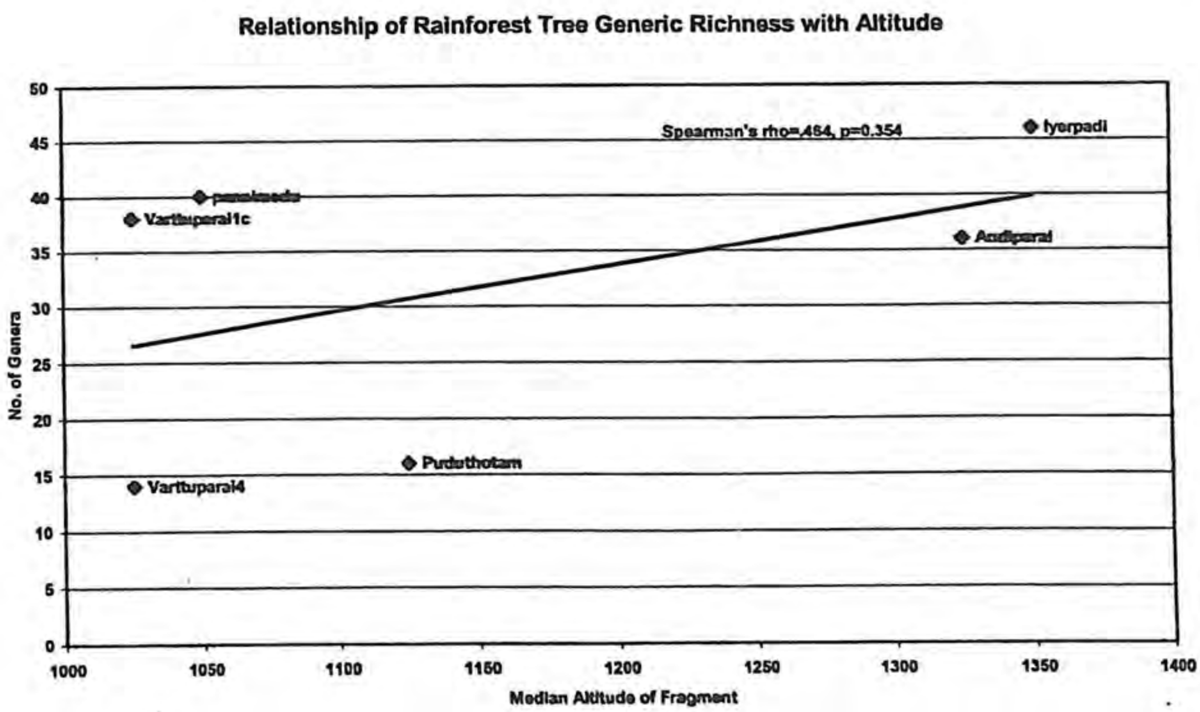


Figure 14b – Relationship of Rainforest Sapling Generic Richness with Altitude

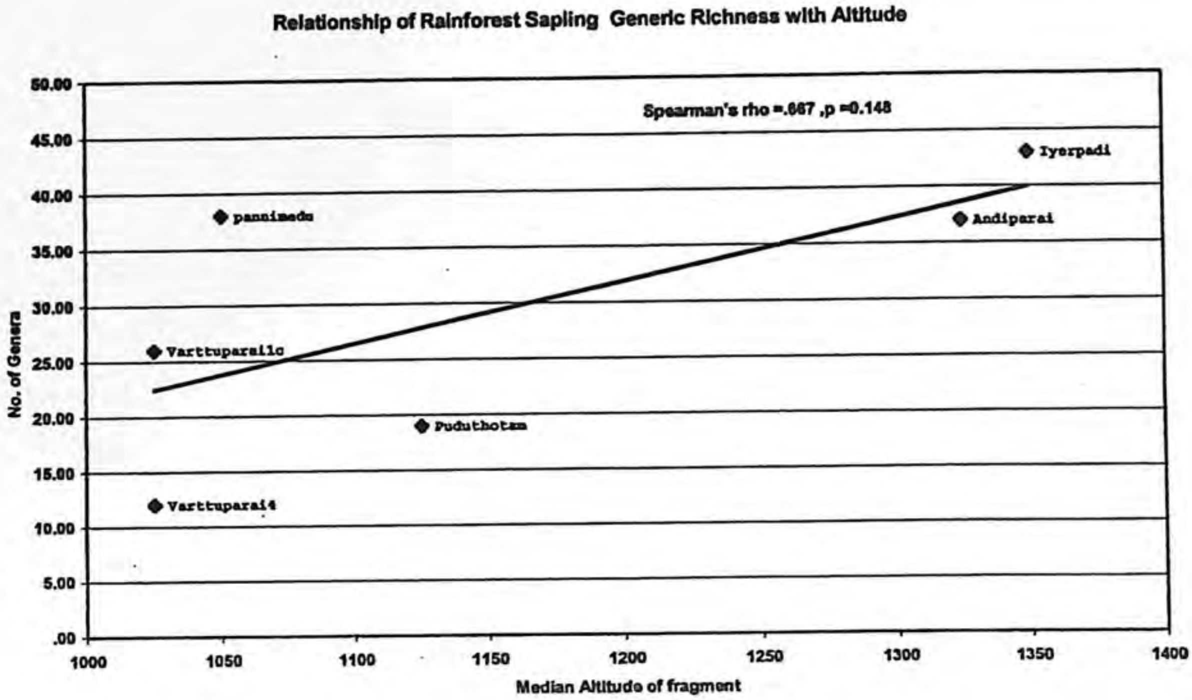
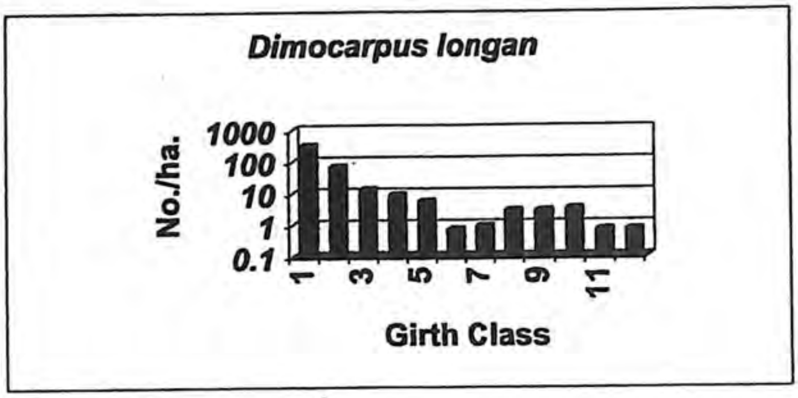


Fig. 15 – Girth class density distribution of select species

15a:



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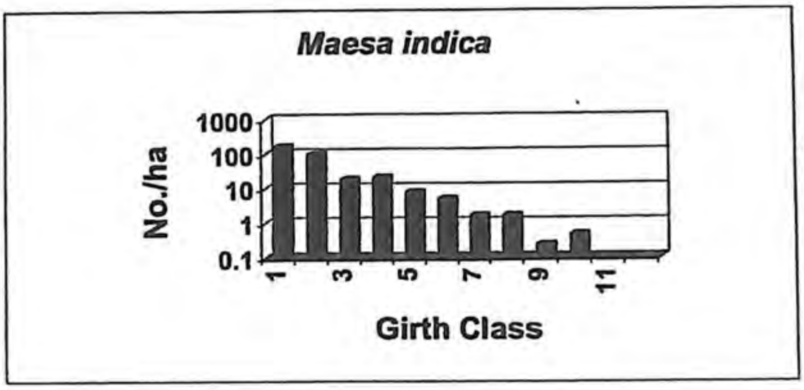
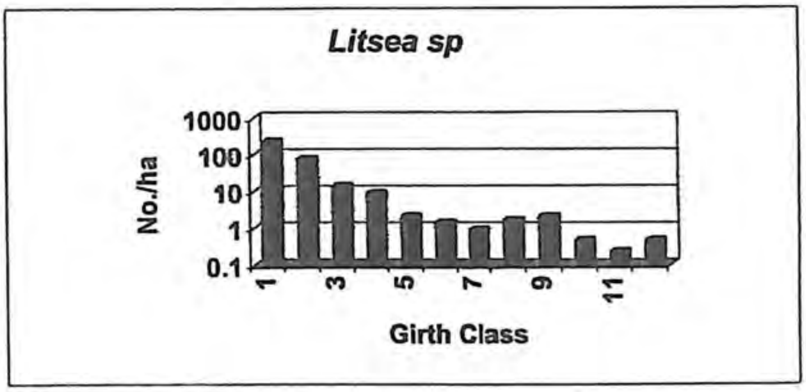
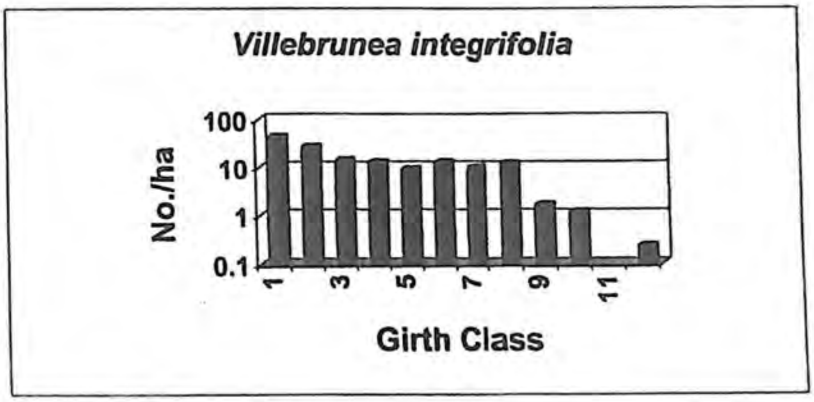


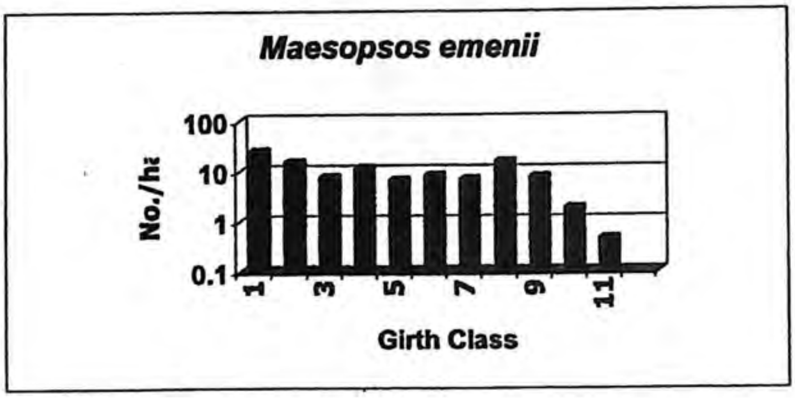
15c:



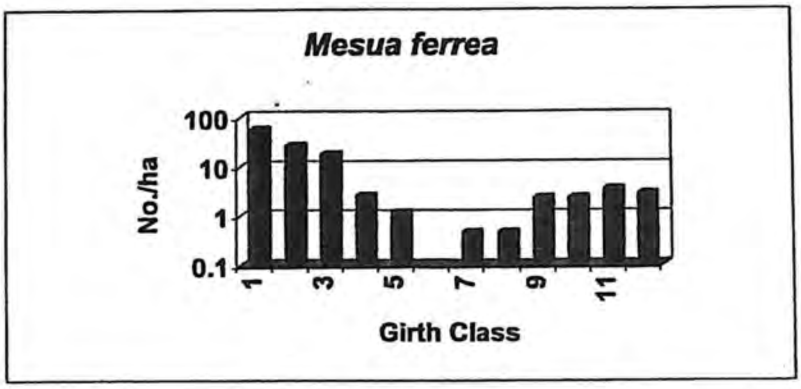
15d:



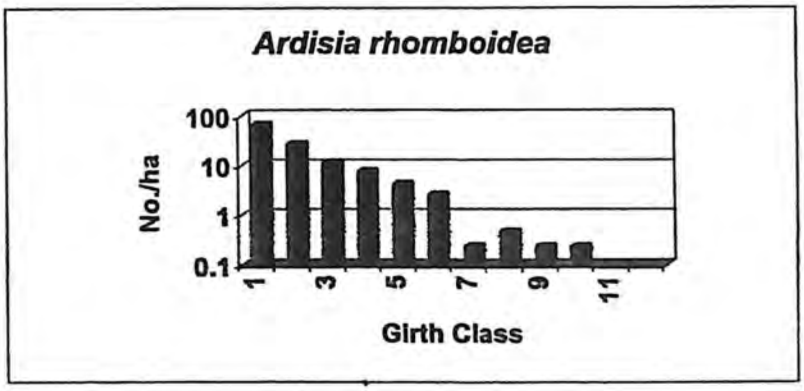
15e:



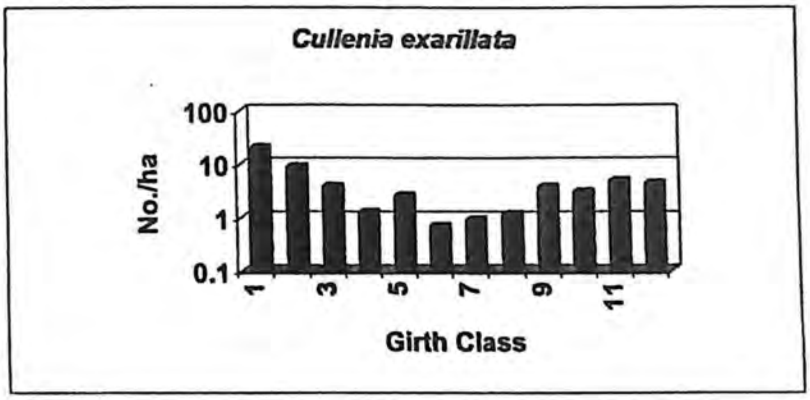
15f:



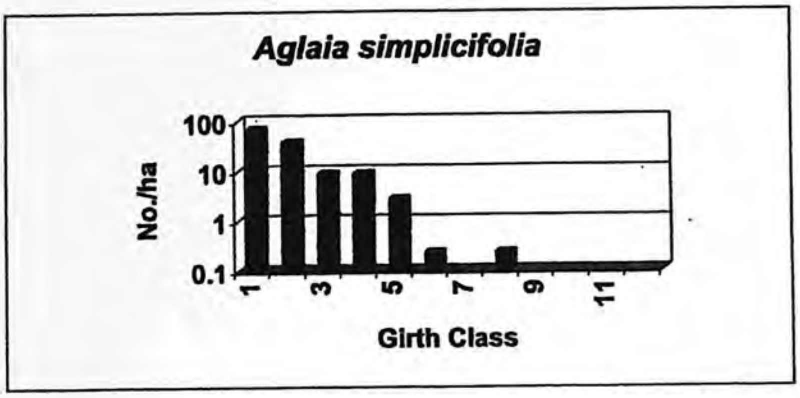
15g:



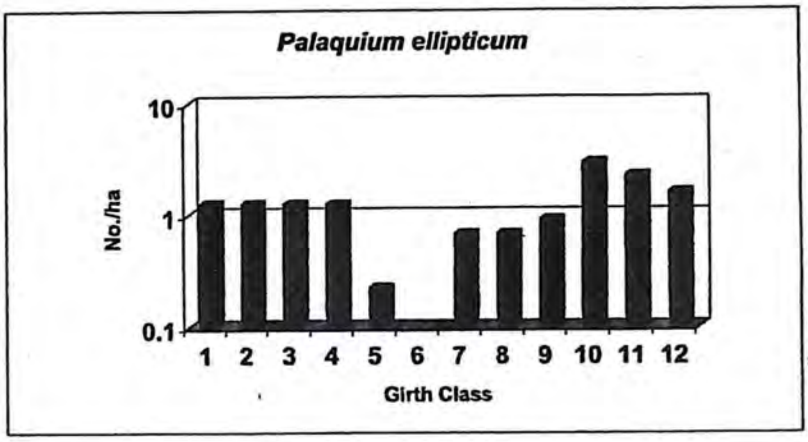
15h:



15i:



15j:



X Axis legend:

Girth Class ID	Girth Class (in cm)
1	1-5
2	5-10
3	10-15
4	15-20
5	20-30
6	30-40
7	40-50
8	50-75
9	75-100
10	100-150
11	150-200
12	> 200

5. DISCUSSION

5.1 TRENDS IN TREE FLORISTIC COMPOSITION AND STRUCTURE

Analyses on the effects of habitat fragmentation have generally been based on the conceptual framework of island biogeography theory (Preston, 1992, MacArthur and Wilson, 1967) which related changes in fragmented habitats to variables such as area (Laurance *et al.* 2001) and time since isolation (Ross *et al.* 2002). The few studies that have also dealt with disturbance have mostly focussed on natural disturbance, however few studies have studied impact of human disturbance on the isolates (Kapos *et al.* 1997). The rainforest fragments of the Valparai region are anomalous in their relationships of generic richness of rainforest trees to area (see section 4.5.3) though a broad pattern of increase in richness with area does exist (Fig. 12a).

The fragments deviant from the conventional relationship namely Puduthotam which shows lower richness compared to its relatively large size and Varattuparai 1c which shows greater richness compared to its small size are noteworthy in both being relatively highly disturbed (Fig. 5). Puduthotam is a chronically disturbed fragment. It was initially underplanted with Cardamom which necessitates the removal of the existing understorey (*pers comm* T. R. Shankar Raman and Divya Mudappa). This would have caused a considerable loss of natural vegetation. After the abandonment of the plantation, Puduthtotam now faces disturbance in the form of high levels of tree cutting, invasion by non rainforest trees principally *Maesopsos emenii* and abundance of non rainforest seedlings, principally coffee (see Fig. 5). *Maesopsos emenii* is a common shade tree used in coffee plantations and its fruits along with coffee are fed on by animals such as Great Pied Hornbills that act as effective dispersers ensuring their regeneration. Puduthotam by its location in the heart of the Valparai town is also the sole fragment supporting the fuelwood needs of the people and industries in that area. This has led to increased cutting of trees and saplings leaving the fragment poor in richness and abundance of genera. Puduthotam would also have scored very high on the numbers of lopped saplings if it was not for the fact that the felling practice involves cutting the saplings right at the base, leaving very few traces of their existence and hence, some underestimation in the numbers of lopped saplings in the fragment has occurred. The above mentioned levels and nature of disturbance translates into very poor generic richness and consequent changes in composition (see section 4.5.3, 4.5.4). The 3 dominant species in Puduthotam are *Maesopsos emenii* , *Macaranga peltata* and *Maesa indica* which together contribute 84% of the tree abundance (Appendix. 3A). *M. emenii* alone contributes about 61% of the tree abundance (Fig. 7.a, Appendix. 3A). *Macaranga* (Richards, 1981, Gomez-Pompa *et al.* 1991) and *Maesa* are both disturbance adapted species which grow well under open canopy. Though *Mesua ferrea* and *Cullenia exarillata*, species characteristic of these forests (Pascal, 1988) are ranked fourth and fifth in abundance they contribute only about 6% of the total abundance (Fig. 7.a, Appendix. 3A). A majority of these trees are also girdled (*pers obs*) indicating their imminent decline. **Varattuparai 1c** is a small fragment (see Table 1) which is surprisingly rich in tree flora (see Table 5). However, on closer inspection some of the dominant species in this fragment was as expected *Maesopsos emenii* and *Maesa indica* (Appendix. 3A). Their dominance signifies a relatively high level of disturbance such as high percentage of open canopy (see section 4.2.1) It is also important to note that out of the 38 genera of rainforest trees found in Varattuparai 1c, 14 genera were represented only by a single individual. This is much higher than observed for the other fragments where singletons are present but not very abundant. This could be because many species of large trees can have very long generation times and thus may respond slowly to fragmentation (Laurance, 1997). Also, some of the species occurring there such as *Chrysophyllum lanceolatum, Zanthoxylum rhetsa* and *Harpullia arborea* are by nature rare at those altitudes (*pers comm* Divya Mudappa and T.R.Shankar Raman) as evident by their absence from the other fragments (Appendix. 3A). Their extremely low relative abundance and non representation at the sapling stage (Appendix. 3B) signifies their imminent decline.

However, very small fragments such as Varattuaparai 4 (see Table 1) and large fragments such as Iyerpadi and Andiparai (see Table 1) show lower and higher richness respectively (see Table. 5). The corresponding differences in the richness are also paralleled by changes in composition and relative abundance (see section 4.4.6, Appendix. 3A). Iyerpadi is dominated by species of family Lauraceae, Principally *Litsea sp* (41trees/ha). Understorey trees such as *Gomphandra coriacea* (29 trees/ha) and *Ardisia rhomboidea* (Pascal, 1988) (20 trees/ha), which may be shade tolerant are also abundant indicative of relatively high canopy closure (see section 4.2.1, Fig. 4) and relatively low disturbance levels prevalent there (Fig. 5). Similarly, Andiparai is abundant in *Hydnocarpus alpina* (33 trees/ha), *Cullenia exarillata* (27 trees/ha) and endemics such as *Mastixia arborea* (21trees/ha). Pannimedu which is a medium sized fragment (See Table 1) is abundant in trees such as *Dimocarpus longan* (49 trees/ha), *Cullenia exarillata* (38 trees/ha) and *Palaquium ellipticum* (31 trees /ha). The densities of *Macaranga peltata* (27 trees /ha), a species that grows in canopy openings (Pascal, 1988) in Pannimedu is almost comparable to those of Puduthotam indicating some canopy openness in the past in Pannimedu. However, there is no representation of the species in the regenerating girth class indicating possible recovery of the fragment. It is also noteworthy that *P. ellipticum* does not occur in such abundance anywhere else. However, the reason for this is unknown.

Altitude is known to govern change in vegetation communities in these hilly areas (Pascal, 1988). This refers to an obvious and marked change in community types such as wet evergreen forests to shola –grassland complex. The insignificant results (section 4.5.3) on the influence of altitude on vegetation composition across fragments corroborate our beliefs on an overall similarity in vegetation in relatively undisturbed fragments between altitiudes of 1000-1500m as seen by the similarities between Pannimedu, Andiparai and Iyerpadi (see section 4.5.4, Fig 9a).

The relationship between disturbance levels and isolation time (see section 4.5.2) is evident in the degree of compositional differences between relatively younger, undisturbed and relatively older disturbed fragments (Fig. 9a) Disturbance thus, by its relationship with all other fragment characters (see section. 4.5.2) seems to play a pivotal role in affecting community composition.

5.2 TRENDS IN SAPLING FLORISTIC COMPOSITION AND STRUCTURE

The overall trend of sapling generic richness shows many peculiarities with typical variables associated with fragmentation such as, area, with medium sized and small sized fragments showing greater or comparable richness with that of large areas. (see Table. 5). However, there does seem to be a slightly consistent trend in the relationship of richness and composition with the magnitude and nature of disturbance. In fragments such as Varattuparai 4, the high levels of invasion by weeds and non rainforest species (see section 4.2.2 Fig. 5,) has resulted in non rainforest plants such as coffee and disturbance adapted species such as *Maesa indica* as some of the dominants. 29% of the saplings of Varattuparai 4 are composed of an unidentified non rainforest species. Puduthotam , though a relatively highly disturbed fragment (see section 4.2.2, Fig. 5)shows high densities of rainforest saplings due to the enhanced regneration of *Dimocarpus longan* , a light tolerant rainforest species (Pascal, 1988) signifying greater canopy openeness (Fig 15a). Apart from this, the other dominant species in the sapling stage is *Maesa indica* (Appendix. 3A). Though *Mesua ferrea* is ranked third in dominance, it contributes only 6% to the total regeneration. This is because, the timber of Mesua ferrea is highly priced and hence, very few poles of *Mesua ferrea* are left to regenerate in these disturbed fragments (*pers comm* Divya Mudappa and T. R. Shankar Raman). The magnitude of regeneration of Coffee in Puduthotam is undocumented (see Table. 4) due to an underestimation of Coffee stems . On the contrary, in relatively undisturbed fragments such as Iyerpadi and Andiparai, the abundances of rainforest saplings is higher (see Table. 4) with a corresponding decrease in abundance of non rainforest saplings and disturbance adapted species. In Iyerpadi, about 25% of the observed saplings were of *Litsea sp* while the second most abundant was *Dimocarpus longan* with only 6%. In Andiparai, the dominant saplings were understorey plants such as *Meiogyne* , *Aglaia* and also *Mesua*. The dominance of rainforest plants and understorey plants may suggest a greater degree of canopy closure.

Stand structure is frequently used to interpret the regeneration process of forests (Fensham and Bowman, 1992, Kadavul and Parthasarathy, 2000). Also, several tropical forest studies have shown the floristic composition of the upper canopy stratum to be different from that of the sapling strata (Richards 1996, Jones *et al.*1994, Uhl and Murphy 1981, Cao and Zhang 1997). Similar patterns of non correspondence between the tree and the sapling layer was found for all fragments (Fig. 6.a-f). However, the mechanism of change in the relatively undisturbed fragments may be better understood keeping in mind the mosaic theory of regeneration proposed by Aubrévillé (Richards, 1996). According to him, the particular combination of species that forms the dominants of a given small area of mixed tropical forest is constant neither in space nor time. The combination of species at a given place is succeeded by a different combination. Though such an inference may be premature at this stage, the dynamic nature of these forests and the ever present force of human disturbance may effect such changes.

The overall girth class distributions of a few ecologically characteristic species in the landscape, such as *Mesua ferrea, Maesopsos emenii and Maesa indica* suggests the importance of human disturbance in the persistence of these species (Fig. 15). The enhanced regeneration of *M. indica* and established trees of *M. emenii* highlight the importance of human disturbance in facilitating the persistence of these species, whereas the low representation of *M. Sferrea* in all the girth classes also reflects the pressures human disturbance can subject these plants to.

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APPENDIX

APPENDIX 1: LIST OF TREE SPECIES IDENTIFIED IN STUDY AREA

Family	Species	AN	IP	PN	PU	V1 C	V4
Anacardiaceae	*Semecarpus travancorica*			1		1	1
	Holigarna nigra		1	1	1		1
	Nothopegia racemosa		1				
	Mangifera indica			1			1
	Nothopegia sp		1				
Annonaceae	*Meiogyne pannosa*	1	1	1			
Apocynaceae	*Alstonia scholaris*					1	1
Araliaceae	*Schefflera micrantha*					1	
Asteraceae	*Vernonia monosis*			1		1	1
Bignoniaceae	*Spathodia campanulata*				1		
Bombacaceae	*Cullenia exarillata*	1	1	1	1		1
Burseraceae	*Canarium strictum*	1	1	1	1		
Celastraceae	*Microtropis latifolia*	1	1		1	1	
	Bhesa indica		1	1			
Clusiaceae	*Mesua ferrea*	1	1	1	1	1	
	Garcinia pictorius		1				
	Calophyllum austroindicum	1	1	1			
	Calophyllum sp	1	1				
	Calophyllum polyanthum		1				
	Garcinia morella		1				
Cornaceae	*Mastixia arborea*	1	1	1		1	
Ebenaceae	*Diospyros sp*	1	1	1		1	1
	Diospyros nilagirica		1				
	Diospyros saldanhae	1					
	Diospyros sylvatica			1			
	Diospyros assimilis	1					
Elaeocarpaceae	*Elaeocarpus serratus/glandulosus*		1		1		
	Elaeocarpus tuberculatus		1	1			
Euphorbiaceae	*Croton zeylanicus*	1	1	1		1	
	Macaranga peltata	1	1	1	1	1	1
	Agrostistachys meeboldii	1	1	1			
	Antidesma menasu	1	1	1		1	1
	Croton sp	1					
	Epiprinus mallotiformis			1		1	
	Mallotus stenanthus	1	1				
	Mallotus tetracoccus	1			1	1	1
	Glochidion malabaricum			1		1	
	Agrostistachys indica	1	1				
	Bischofia javanica				1		
	Fahrenheitia zeylanica					1	
	Glochidion sp			1			
	Aporosa bourdilloni					1	
	Glochidion johnstonei		1				
Fabaceae	*Ormosia travancorica*				1		
	Erythrina indica					1	
Flacourtiaceae	*Hydnocarpus alpina*	1	1				1
	Casearia sp	1	1				

Family	Species	AN	IP	PN	PU	V1 C	V4
	Casearia rubescens	1	1				
	Scolopia crenata	1	1				
Icacinaceae	*Gomphandra coriacea*		1	1		1	
	Nothapodytes foetida	1		1			
Lauraceae	*Litsea sp*	1	1	1		1	
	Persea macrantha	1	1	1		1	1
	Apollonias arnottii		1	1		1	1
	Litsea/Cryptocarya sp		1			1	
Lauraceae	*? Phoebe sp?*		1				
	Litsea bourdilloni	1	1	1		1	
	Cinnamomum malabathrum	1	1	1	1	1	1
	Neolitsea zeylanica	1	1	1		1	
	Actinodaphne sp	1	1	1		1	
	Beilschmiedia wightii	1	1				
	Actinodaphne tadulingami	1	1	1			
	Neolitsea sp	1	1	1			
	Litsea floribunda	1		1		1	
	Cryptocarya sp	1	1	1			
	Cinnamomum sp		1	1			
	Neolitsea scrobiculata	1	1			1	
	Litsea oleoides		1	1		1	
	Cryptocarya bourdilloni			1		1	
	?Actinodaphne tadulingami	1					
	? Apollonias arnottii?	1					
	Litsea/Actinodaphne sp		1				
	Litsea sp2		1				
	Litsea sp1			1			
	Actinodaphne bourdilloni			1			
	Litsea mysorensis		1				
	Actinodaphne sp1			1			
	Actinodaphne sp2		1				
Leeaceae	*Leea indica*	1		1	1		
Melastomataceae	*Memecylon sp*					1	
	Memecylon angustifolium					1	
Meliaceae	*Aglaia simplicifolia*	1	1	1			
	Dysoxylum binectariferum		1	1		1	
	Dysoxylum malabaricum		1	1	1	1	
	Aglaia exstipulata	1		1	1	1	
	Toona ciliata	1		1	1		
	Trichilia connaroides	1			1		
	Dysoxylum sp					1	
Moraceae	*Artocarpus heterophyllus*	1	1	1	1		1
	Ficus nervosa		1	1	1		1
	Ficus exasperata				1	1	1
	Ficus sp		1				
	Ficus hispida			1	1		
	Ficus tsjahela	1					
Myristicaceae	*Myristica dactyloides*	1	1	1			
Myrsinaceae	*Maesa indica*	1	1	1	1	1	1
	Ardisia rhomboidea	1	1	1			
Myrtaceae	*Syzygium munronii*			1			
	Syzygium heyneanum	1	1	1		1	

Family	Species	AN	IP	PN	PU	V1 C	V4
	Syzigium gardneri	1	1	1			
	Eugenia thwaitesii			1		1	
	Syzigium sp	1	1	1			
	Syzigium cumini			1		1	
	Syzigium hemisphericum	1		1			
	Syzigium zeylanicum var zeylanicum		1				
	Syzigium occidentale				1		
	Syzigium laetum					1	
	Syzigium travancoricum			1			
Oleaceae	*Olea dioica*	1			1		
Rhamnaceae	*Maesopsos emenii*				1	1	1
Rubiaceae	*Coffee sp*	1		1		1	1
Rubiaceae	*Tricalysia apiocarpa*	1	1				
	Canthium dicoccum	1					
Rutaceae	*Acronychia pedunculata*	1	1	1	1	1	
	Atalantia racemosa		1	1		1	
	Murraya paniculata	1	1	1		1	
	Vepris bilocularis				1	1	
	?Atalantia sp?				1	1	
	Zanthoxylum rhetsa					1	
	Syzigium munronii			1			
	Euodia lunu-ankenda			1			
Sabiaceae	*Meliosma pinnata ssp arnottiana*			1		1	
	Meliosma simplicifolia ssp simplicifolia		1				
Sapindaceae	*Dimocarpus longan*	1	1	1	1	1	1
	Lepisanthes decipiens		1				1
	Harpullia arborea					1	
Sapotaceae	*Palaquium ellipticum*	1	1	1		1	1
	Chrysophyllum lanceolatum					1	
Sterculiaceae	*Heritiera papilio*	1	1	1	1		
	Sterculia guttata					1	
Symplococaceae	*Symplocos macrophylla ssp rosea*						1
Urticaceae	*Villebrunea integrifolia*	1	1	1	1	1	1
	Dendrocnide sinuata			1			
Verbenaceae	*Callicarpa tomentosa*	1				1	1
Xanthophyllaceae	*Xanthophyllum flavescens*					1	

APPENDIX 2: LIST OF ENDEMIC TREE SPECIES IDENTIFIED IN STUDY AREA

Family	Species	an	ip	pn	pu	v1c	v4
Anacardiaceae	*Holigama nigra*		1	1	1		1
	Semecarpus travancorica			1		1	1
Annonaceae	*Meiogyne pannosa*	1	1	1			
Celastraceae	*Microtropis latifolia*	1	1		1	1	
Clusiaceae	*Calophyllum austroindicum*	1	1	1			
Cornaceae	*Mastixia arborea*	1	1	1		1	
Ebenaceae	*Diospyros assimilis*	1					
	Diospyros nilagirica		1				
	Diospyros saldanhae	1					
Euphorbiaceae	*Aporosa bourdilloni*					1	
	Glochidion johnstonei		1				
	Glochidion malabaricum			1		1	
	Mallotus stenanthus	1	1				
Fabaceae	*Ormosia travancorica*				1		
Flacourtiaceae	*Casearia rubescens*	1	1				
Lauraceae	*Actinodaphne bourdilloni*			1			
	Actinodaphne tadulingami	1	1	1			
	Apollonias arnottii		1	1		1	1
	Beilschmiedia wightii	1	1				
	Cinnamomum malabathrum	1	1	1	1	1	1
	Cryptocarya bourdilloni			1		1	
	Litsea bourdilloni	1	1	1		1	
	Litsea floribunda	1		1		1	
	Litsea mysorensis		1				
Meliaceae	*Aglaia exstipulata*	1		1	1	1	
	Aglaia simplicifolia	1	1	1			
	Dysoxylum malabaricum		1	1	1	1	
Myrsinaceae	*Ardisia rhomboidea*	1	1	1			
Myrtaceae	*Syzigium laetum*					1	
	Syzigium occidentale				1		
	Syzigium travancoricum			1			
Rubiaceae	*Tricalysia apiocarpa*	1	1				
Rutaceae	*Euodia lunu-ankenda*			1			
	Vepris bilocularis				1	1	
Sapotaceae	*Palaquium ellipticum*	1	1	1		1	1
Sterculiaceae	*Heritiera papilio*	1	1	1	1		
Symplococaceae	*Symplocos macrophylla ssp rosea*						1
		19	21	21	9	15	6

APPENDIX 3A: RANK ABUNDANCE PLOT OF TREE SPECIES IN STUDY AREA

AN	% Abd	IP	% Abd	PN	% Abd	PU	% Abd	V 1C	% Abd	V4	% bd
Hydnocarpus	13.86555	Litsea	9.951456	Dimocarpus	13.1016	Maesopsos	61.11111	Maesopsos	19.375	Abc	32
Cullenia	11.34454	Gomphandra	7.038835	Cullenia	10.16043	Macaranga	12.15278	Acronychia	14.375	Ficus	12
Croton	10.08403	Hydnocarpus	5.582524	Agrostistachys	8.55615	Maesa	11.11111	Maesa	13.75	Macaranga	8
Mastixia	8.823529	Diospyros	5.339806	Palaquium	8.28877	Mesua	3.472222	Apollonias	3.75	Maesopsos	8
Mesua	7.563025	Ardisia	4.854369	Macaranga	7.219251	Cullenia	3.125	Callicarpa	3.75	Mangifera	8
Mallotus	6.722689	Mesua	4.854369	Acronychia	6.684492	Dimocarpus	2.430556	Dimocarpus	3.75	Artocarpus	4
Ardisia	4.621849	Cullenia	4.368932	Epiprinus	4.278075	Artocarpus	1.388889	Eugenia	3.75	Callicarpa	4
Actinodaphne	3.361345	Mastixia	3.883495	Mastixia	3.208556	Ficus	1.388889	Cinnamomum	3.125	Holigarna	4
Dimocarpus	2.941176	Bhesa	3.640777	Myristica	3.208556	Abc	0.694444	Dysoxylum	3.125	Hydnocarpus	4
Litsea	2.941176	Acronychia	3.15534	Antidesma	2.941176	Elaeocarpus	0.694444	Litsea	3.125	Maesa	4
Artocarpus	2.521008	Garcinia	3.15534	Dendrocnide	2.941176	Aglaia	0.347222	Macaranga	3.125	Mallotus	4
Acronychia	2.10084	Lepisanthes	3.15534	Litsea	2.941176	Bischofia	0.347222	Aglaia	1.875	Palaquium	4
Aglaia	2.10084	Litsea/Cryptocarya	3.15534	Croton	2.673797	Canarium	0.347222	Antidesma	1.875	Semecarpus	4
Agrostistachys	2.10084	Agrostistachys	2.669903	Semecarpus	2.673797	Cinnamomum	0.347222	Epiprinus	1.875		
Callicarpa	2.10084	Heritiera	2.669903	Maesa	2.406417	Dysoxylum	0.347222	Meliosma	1.875		
Antidesma	1.680672	Myristica	2.669903	Mesua	2.406417	Holigarna	0.347222	Actinodaphne	1.25		
Calophyllum	1.680672	Aglaia	2.427184	Diospyros	1.871658	Spathodia	0.347222	Ficus	1.25		
Leea	1.680672	Maesa	2.427184	Apollonias	1.604278			Glochidion	1.25		
Macaranga	1.680672	Dimocarpus	2.184466	Persea	1.336898			Mallotus	1.25		
Maesa	1.680672	Antidesma	1.941748	Actinodaphne	1.069519			Murraya	1.25		
Heritiera	1.260504	Neolitsea	1.941748	Aglaia	1.069519			Palaquium	1.25		
Persea	1.260504	Beilschmiedia	1.699029	Artocarpus	1.069519			Schefflera	1.25		
Cinnamomum	0.840336	Casearia	1.699029	Meiogyne	1.069519			Alstonia	0.625		
Myristica	0.840336	Palaquium	1.699029	Ardisia	0.802139			Aporosa	0.625		
Neolitsea	0.840336	Calophyllum	1.456311	Canarium	0.802139			Atalantia	0.625		
Canarium	0.420168	Cinnamomum	1.213592	Glochidion	0.802139			Chrysophyllum	0.625		
Canthium	0.420168	Nothopegia	1.213592	Holigarna	0.802139			Cryptocarya	0.625		
Coffee	0.420168	Actinodaphne	0.970874	Bhesa	0.534759			Erythrina	0.625		

AN	% Abd	IP	% Abd	PN	% Abd	PU	% Abd	V 1C	% Abd	V4	% bd
Cryptocarya	0.420168	Artocarpus	0.970874	Calophyllum	0.534759			Harpullia	0.625		
Ficus	0.420168	Croton	0.970874	Cinnamomum	0.534759			Litsea/Cryptocarya	0.625		
Murraya	0.420168	Cryptocarya	0.970874	Elaeocarpus	0.534759			Mastixia	0.625		
Palaquium	0.420168	Elaeocarpus	0.970874	Gomphandra	0.534759			Mesua	0.625		
Scolopia	0.420168	Scolopia	0.970874	Neolitsea	0.534759			Neolitsea	0.625		
		Atalantia	0.728155	Cryptocarya	0.26738			Persea	0.625		
		Macaranga	0.728155	Dysoxylum	0.26738			Semecarpus	0.625		
		Ficus	0.485437	Mangifera	0.26738			Sterculia	0.625		
		Murraya	0.485437								
		Persea	0.485437								
		Apollonias	0.242718								
		Canarium	0.242718								
		Glochidion	0.242718								
		Holigarna	0.242718								
		Meliosma	0.242718								

APPENDIX 3B: RANK ABUNDANCE PLOT OF TREE SAPLINGS IN STUDY AREA

AN	% Abd.	IP	% Abd.	PN	% Abd.	PU	% Abd.	V1C	% Abd.	V4	% Abd.
Meiogyne	15.31	Litsea	25.41	Croton	19.41	Dimocarpus	39.62	Coffee	18.80	Abc	29.17
Aglaia	10.94	Dimocarpus	6.53	Syzigium	18.24	Maesa	32.08	Dimocarpus	15.04	Maesa	18.75
Mesua	8.13	Croton	6.26	Villebrunea	11.37	Mesua	6.13	Maesa	9.77	Coffee	14.58
Ardisia	7.19	Ardisia	5.81	Apollonias	5.69	Leea	4.48	Croton	9.02	Cullenia	8.33
Persea	6.88	Heritiera	5.26	Dimocarpus	5.49	Heritiera	3.77	Maesopsos	9.02	Persea	6.25
Heritiera	5.94	?Phoebe	5.17	Maesa	4.31	Maesopsos	3.77	Eugenia	5.26	Maesopsos	4.17
Maesa	5.63	Aglaia	4.26	Litsea	4.12	Cullenia	1.89	Apollonias	4.14	Alstonia	2.08
Casearia	4.69	Litsea/Cryptocarya	4.26	Meiogyne	3.92	Macaranga	1.89	Persea	4.14	Antidesma	2.08
Actinodaphne	4.38	Atalantia	3.18	Aglaia	3.73	Abc	1.42	Dysoxylum	3.76	Apollonias	2.08
Cullenia	3.75	Neolitsea	3.18	Dysoxylum	3.73	Vepris	0.94	Acronychia	3.38	Artocarpus	2.08
Diospyros	3.44	Casearia	2.90	Atalantia	3.53	?Atalantia	0.71	Atalantia	2.63	Callicarpa	2.08
Hydnocarpus	2.50	Microtropis	2.72	Persea	2.35	Trichilia	0.71	Cinnamomum	2.63	Cinnamomum	2.08
Mastixia	2.50	Syzigium	2.72	Dendrocnide	1.76	Olea	0.47	Litsea	2.63	Dimocarpus	2.08
Neolitsea	1.88	Cinnamomum	2.27	Mesua	1.76	Toona	0.47	Mesua	2.26	Diospyros	2.08
Syzigium	1.88	Maesa	1.63	Coffee	1.57	Acronychia	0.24	Neolitsea	1.13	Lepisanthes	2.08
Villebrunea	1.88	Actinodaphne	1.54	Acronychia	1.18	Aglaia	0.24	Callicarpa	0.75		
Coffee	1.25	Beilschmiedia	1.54	Diospyros	0.98	Ficus	0.24	Cryptocarya	0.75		
Dimocarpus	1.25	Tricalysia	1.54	Mastixia	0.59	Mallotus	0.24	Memecylon	0.75		
Litsea	0.94	Persea	1.45	Palaquium	0.59	Microtropis	0.24	Microtropis	0.75		
Microtropis	0.94	Lepisanthes	1.27	Actinodaphne	0.39	Ormosia	0.24	?Atalantia	0.38		
Myristica	0.94	Mesua	1.18	Agrostistachys	0.39	Syzigium	0.24	Aglaia	0.38		
Trichilia	0.94	Diospyros	1.09	Cinnamomum	0.39			Diospyros	0.38		
?Actinodaphne	0.63	Hydnocarpus	1.09	Cullenia	0.39			Fahrenheitia	0.38		
?Apollonias	0.63	Apollonias	0.82	Epiprinus	0.39			Gomphandra	0.38		
Beilschmiedia	0.63	Mastixia	0.82	Eugenia	0.39			Murraya	0.38		
Cinnamomum	0.63	Murraya	0.82	Ficus	0.39			Syzigium	0.38		
Croton	0.63	Myristica	0.64	Leea	0.39			Vepris	0.38		

AN	% Abd.	IP	% Abd.	PN	% Abd.	PU	% Abd.	V1C	% Abd.	V4	% Abd.
Scolopia	0.63	Acronychia	0.54	**Meliosma**	0.39			**Vernonia**	0.38		
Agrostistachys	0.31	Antidesma	0.54	**Antidesma**	0.20						
Artocarpus	0.31	Villebrunea	0.54	**Ardisia**	0.20						
Callicarpa	0.31	Calophyllum	0.45	**Bhesa**	0.20						
Cryptocarya	0.31	Dysoxylum	0.45	**Cryptocarya**	0.20						
Leea	0.31	Meiogyne	0.36	**Euodia**	0.20						
Mallotus	0.31	Scolopia	0.36	**Glochidion**	0.20						
Murraya	0.31	Ficus	0.27	**Gomphandra**	0.20						
Nothapodytes	0.31	Gomphandra	0.27	**Heritiera**	0.20						
Olea	0.31	Litsea/Actinodaphne	0.18	**Murraya**	0.20						
Tricalysia	0.31	Mallotus	0.18	**Myristica**	0.20						
		Agrostistachys	0.09	**Nothapodytes**	0.20						
		Cryptocarya	0.09								
		Cullenia	0.09								
		Macaranga	0.09								
		Nothopegia	0.09								